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Heresy Concerning Specialized Physics Courses

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THE art of teaching is not free from the stagnating influence of the inertia of custom. Indeed, the changes that are made in our teaching habits are more dependent upon outside influences than perhaps we will frankly admit. Consider, for example, the requirement of trigonometry as a prerequisite for a college course in physics. Thirty or more years ago this requirement was practically universal. But those who fixed the college requirements for entrance into medicine paid no attention to such orthodoxy and demanded a college course in physics without the trigonometry prerequisite. Physics teachers, protestingly it is true, finally provided the course as demanded. One would scarcely think from this example that physics teachers have been on the alert, looking for opportunities of service, but rather that we have reluctantly accepted demands made upon us. Regretfully we must admit that there have been very few changes in college physics teaching during the past sixty years and even such as have occurred may be traced to outside demands. About sixty years ago laboratory work for students was introduced for the first time. It was an American innovation. In some colleges this novel way of teaching created quite a sensation, arousing the interests of the students to a high pitch and giving the subject of physics apparently too much emphasis, according to the statements of other departments.[1] But since that day physics has produced no new devices of such a sweeping nature. We have had experimental lectures, recitations, laboratory periods and for sixty years the development of physics teaching has been somewhat uneventful. This fact does not indicate that we have necessarily erred in making so few changes, but it does show that we are quite accustomed to the acceptance and consequent retention of standardized practices.

One of our traditions is that if any one needs physics at all, his first step should be a course in general physics. For, verily, how can a man acquire any advantage from only a selected part of the field unless he has an elementary knowledge of the various topics that are involved in "general physics"? Any variation from this tradition is heresy, but an experience of the author covering the past ten years has compelled him to forsake the tradition and advocate its abandonment. This experience can be related with considerable humility, for the author did not initiate the teaching venture. It was thrust upon him. Dean C. E. Seashore, as head of the department of psychology at the University of Iowa, finding his laboratory more and more dependent upon acoustics, requested that his graduate students be given a course for one semester in that subject. There could be no prerequisites in mathematics or physics. Some of the students would have had high school

[1] Such laboratory work was given at the Massachusetts Institute of Technology in 1869 and at the University of Iowa, and doubtless elsewhere, in 1870. Those who were connected with Iowa at that time have told the author of the complaints on the part of the other members of the faculty.

physics and some of them no physics at all. The author was somewhat skeptical of the outcome. Later, to the group of graduate students in psychology were added those in the department of speech. Still later all juniors and seniors majoring in music were added. Today this is the group being taught acoustics for three hours per week for one semester. It is presented without laboratory and lectures. Of course numerous illustrative experiments which help develop adequate concepts are used, but the course is based upon assignments in the author's text, *Introductory Acoustics*.[2] The subject matter covers all the most common phenomena and many that are rather unusual and interesting. The students, nonscientific and previously untrained in reasoning in physical science, do acquire an amazing understanding. Not only has the heretical experiment proved successful so far as learning is concerned, but the experience has seriously modified certain of the writer's views. Without indicating these changes, a statement of that which it seems advisable to emphasize at this time is perhaps appropriate. This may be presented in the form of the following conclusions:

(1) Specialized courses in undergraduate physics can be successfully taught without a preceding elementary general course and with but very little mathematics.

(2) The mind is not as interested in a rapid review of phenomena or any bird's-eye view of physics as it is in analysis and other serious mental efforts. Thus, specialized courses in physics arouse more interest than do less profound general courses.

(3) By avoidance of mathematics in such a course, a greater stress must be laid upon verbal analysis and clear statements which show the thinking process. The absence of symbolic help expressed through mathematics increases, so it seems, the clearness of the concept in the mind of the student.

(4) The implication in the preceding statement deserves a separate statement, to wit: the orthodox insistence of the use of mathematics for the purpose of developing clearer concepts is unsound.

(5) A second corollary to the third of the foregoing conclusions is that the "mental depth" of a course in physics and the extent of the use of mathematical symbols do not have a one to one correspondence. The only test is the actual use of the analytical powers of the mind and not the manipulation of symbols.

(6) If a specialized course in physics is profound rather than superficial, the previous preparation in physics proves to be overshadowed in importance by the innate ability of the student.

Perhaps a general discussion bearing upon these conclusions will add clearness and significance. Physicists have in the past insisted upon a preparation in general physics as preliminary to any specialized courses. We have wished students in specialized courses to be initially familiar with physical terms, concepts and principal laws. Obviously such familiarity is an advantage. We have also insisted upon the ability to use mathematics, to solve problems. But we have given no opportunity to those who, without needing calculating skill in physics problems, nevertheless require clear concepts of phenomena. For we have thought that the application of mathematics is essential to the understanding of physical phenomena. This is far from true. Algebra is of course used for economy of thought in elementary physics. But economy of thought and enhancement of clearness of thinking are not synonymous. To the extent that algebraic manipulation relieves us of logical thinking, we lose the opportunity of cultivating clearer concepts. There is a stimulus in mental arithmetic which is lacking in the solution of the same problems by algebra. The experience in teaching acoustics to students of music, psychology and speech, shows that the use of mathematics is not only impractical but ill-advised. In *Introductory Acoustics* there are problems which require for a solution a clear understanding of the phenomena, sometimes even more clear than if the mathematical tools were available for use. As an example of the use of reasoning without mathematics, as early as page 34 in the text occurs the problem, "A piece of cheese cloth is known to stop a wind in a marked manner. Why is it not effective in stopping the passage of sound?" The magnitude of the mean velocity in a sound wave of ordinary intensity is given in the text. With this information the student can answer the question qualitatively without any use of mathematics whatever and in so doing build up his concept of a wave and its properties. It would be most unfortunate to deprive him of this privilege until he can answer the question more quantitatively

[2] G. W. Stewart, *Introductory Acoustics*, D. Van Nostrand Company, New York, 1933. Reviewed in The American Physics Teacher **1**, 19–20 (1933); **1**, 50 (1933).

through the use of symbols and additional assumptions. Here is another question that must be answered if the inquiry of the student's mind is to be satisfied: "Why can two sound waves cross without the propagation of either being modified?" Mathematics will not give the answer. The wave equation does not help. But if the teacher has a clear concept of the wave he at once rests his explanation upon the fact that a wave of small displacement amplitude will not noticeably modify the physical properties of the medium. No mathematical procedure will clarify. Simple straight reasoning is demanded. Indeed, if a student should attempt to answer by using displacement or pressure equations he would probably become confused and might even prove that there would be a resultant wave going in neither of the two initial directions. It is quite incorrect to believe that mathematics is always a help to thinking. Clear concepts are of the first importance, and the current view among physicists that it is impossible to acquire clear concepts without the use of mathematics is decidedly incorrect.

The author has been much surprised at the keen pleasure on the part of the teacher in conducting the course in acoustics described. It is much like teaching an interesting graduate course to those who are becoming physicists. In both cases the student is presumably using his mind at or near its limit. The thinking requires an effort and success is recognized as an achievement. By way of contrast, elementary general physics covers a great deal of ground quite superficially and thus, to a large extent, fails to give those pleasurable rewards which accrue from more profound efforts. It is an interesting commentary that these students in introductory acoustics, most of them initially afraid of science and studying under compulsion, should learn to enjoy the exercise of analyzing ability to a degree that makes the teaching an unusual pleasure.

It is not difficult to guess that the experience of teaching introductory acoustics has emphasized in the author's mind the deficiencies in usual college instruction. We teachers have cultivated too great a respect for broad information and have produced too little thinking that may be termed profound. We have emphasized assignments destined to cover much ground and have been too proud of the student's ability to retain the acquired information. To ask a student to omit some usual assignments in order to give more careful thought to selected material does not conform to present ideas of elementary physics teaching. The response of minds untrained in science to *Introductory Acoustics*, shows the weakness in the superficiality of elementary physics, the loss of educational value in its very breadth. The scrutiny of teaching during the next few years will demand better results for the individual and new methods of testing will be devised which will enable us to ascertain more nearly the value of the contribution of a course in physics to an individual in the development of conscious habits of value.

The success of the specialized course in acoustics has now induced the organization of a similar course on "Light and Color" for dramatic students interested in stage effects. It may be thought that these "background" courses cannot in any manner enable a student subsequently to make quantitative use of his physics. But this is not correct. The students of psychology, with the advantage of clear concepts in acoustics, have been able to develop and to use measuring methods and to contribute to physiological acoustics.

In conclusion it may be emphasized that this brief article is a report of an experience extending over ten years. That experience seems to show clearly that departments of physics everywhere should abandon the tradition of prerequisites and teach a needed specialized course in physics to meet the desires of any college or department. Other nontraditional views, suggested in this article, have also been emphasized by the response of those untrained in science to the course in introductory acoustics.

A Modification of the Traditional Approach to College Physics

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ABOUT four years ago the president of the writer's college asked several departments to restudy the content and mode of presentation of their respective first-year courses from a point of view which could be summarized as follows:

> The registration for a first-year course in a college of liberal arts usually consists of students for the great majority of whom that course will constitute the only curricular experience in that field of knowledge. Notwithstanding this, in the usual design of first-year college courses primary consideration is given to the laying of the best possible foundation for further work in the subject, a secondary place being then accorded to the interests of students who will in all probability do no further work in the subject. To such an extent as this describes the situation within your department, will you study the possibility of reversing the relative positions of these objectives? An intermediate third-semester course is suggested as a possible way of meeting the requirements of students whose preparation for advanced work in the department might be rendered inadequate by such a change in policy.

The problem thus raised was, for physics, obviously a variation of the hoary-headed problem of "arts physics." A question often raised is whether the assumed disparity between the best course for budding specialists and that for nonspecialists actually exists; whether the contrast drawn between the two does not constitute a false dilemma. Recognizing this as a controversial question, incapable of final answer in the general case, there are surely many instances which provide sufficient possibility of improving our curricular material along the line suggested to justify some experimentation.

An impartial "outside" inspector, examining our system of education at the college level, would have some basis for a suspicion that the budding specialists in any field would be likely to receive more than their share of attention. College and university instruction is carried out exclusively by subject experts. In too many cases these experts are primarily subject-matter specialists, and only secondarily educators. This has in large measure been brought about by the adoption of the Ph.D. fetish in higher edication, together with the narrowness of the qualifications that graduate schools have established for the doctorate. We are sometimes loath to admit the need for a broader point of view in college and university instruction, partly because it discloses a breach which some professional educationists are all too eager to fill by legislated methodological panaceas. Nevertheless there is much to justify the question whether the current mode of professional preparation and the stimulus of the usual types of professional rewards have not created a situation which inevitably places the budding specialist at the focus of interest of the college teacher. With the best will in the world, even in the case of one who resolutely puts behind him all conscious consideration of professional recognition, it is very difficult to give the same heartiness of effort to the nonspecialist majority of a first-year class that is spontaneously lavished on the specialist minority. This throws a heavy burden of proof on all who insist that "physics is physics," or that a course which best serves the interest of budding physicists furnishes also the best possible training for everyone else.

After Latin and Greek ceased to be the exclusive media of intellectual exchange, the classics maintained their vested interests in the educational world by proclaiming the general disciplinary value of the ancient languages. For two or three generations the term "formal discipline" was an expression to conjure with in educational theory. The classics associated themselves so intimately with this educational bubble that when it burst the reaction produced an undervaluation of the classics that is becoming perhaps as serious as their earlier overvaluation.

The sciences seem to be in a fair way to repeat this educational debacle. Unless physics aban-

dons its present *sine qua non* of inflicting on elementary classes, under the guise of training in rigorous thinking, the deduction of obscure theorems from unobvious assumptions, with the aid of algebraic processes that are in themselves sources of confusion, she will continue to contribute materially to the reaction which is already looming on the educational horizon. Disillusionment with the laboratory is definitely in the air. It is not dispelled by imposing on unwilling victims of required science courses measurements of natural constants which they never heard of before and will never use again, with instruments whose very technical excellence sometimes obscures whatever fundamental principles may be at issue.

Nevertheless one who undertakes to depart from the beaten path must expect to discover a large lack of unanimity of opinion on the merits of his proposal. Our own venture afield has been frankly tentative and experimental. Very little of the conventional approach was taken for granted, even as fundamental a question as the retention of laboratory work being discussed after locking all doors and satisfying ourselves that none of our scientific associates within range were carrying deadly weapons. It did not require long to decide to retain the laboratory, with the qualification that in the selection of experiments emphasis should be placed on illustration of fundamental principles, with the elimination as far as possible of those whose principal objective was technical.

There followed an analysis of our current laboratory work for the purpose of the separation of these two types of experiment. The line of separation in some cases was not perfectly clear, of course, but with some allowance for differences of opinion, it was found that the regular first-year experiments divided almost evenly between the two classes. Since the same sequence is used at some other places as in Oberlin, it may be of interest to record here our classification.

Of 39 experiments which constituted the annual sequence in the general physics laboratory, 21 were classified as primarily illustrative of principle and 18 as primarily technical, as follows:

ILLUSTRATIVE OF PRINCIPLE

Mechanics

Composition and resolution of forces;
Equilibrium of force moments;
Free fall;
Newton's second law of motion;
Impact;
Power and efficiency;
Centripetal force and mass reaction;
Measurement of g (pendulum method).

Heat and properties of matter

Density and Archimedes' principle;
Boyle's law;
Specific heat;
Mechanical equivalent of heat.

Electricity

Faraday's laws of electrolysis;
Wheatstone's bridge (wire form);
Simple generator;
Distribution of magnetism in a bar magnet;
Characteristics of thermionic vacuum tubes.

Sound

Vibrations of strings.

Light

Lens combinations;
Spectra;
Polarized light.

TECHNICAL

Mechanics

*Rotational inertia;
*Young's modulus;
*Rigidity modulus;
*Torsion pendulum.

Heat and properties of matter

*Coefficient of expansion.

Electricity

*Earth's magnetic field;
Temperature coefficient of resistance;
Specific resistance;
*Potentiometer (box form);
*Galvanometer sensitivity;
*Measurement of capacitance;
*Absolute values of H and V by earth inductor;
Coefficient of self-induction;
*Voltage regulation in direct-current generators.

Sound

*Velocity of sound in steel and in carbon dioxide by Kundt's tube.

Light

Lummer-Brodhun photometer;
Index of refraction by prism spectrometer;
*The grating spectrometer.

The technical experiments are being removed from the first-year course as rapidly as possible, and new experiments substituted which are primarily illustrative of principle. At present, all experiments of the technical list which bear an asterisk have been withdrawn, and substitutions made as follows:

SUBSTITUTIONS AND MAJOR MODIFICATIONS

Mechanics

Composition and resolution of forces;
Equilibrium of force moments.

Heat and properties of matter

Boyle's law.

Electricity

Faraday's laws of electrolysis;
Potentiometer (wire form);
Magnetic field of a solenoid;
Radioactivity.

Sound

Harmonic motion;
Visual modification of sonometer experiment.

Light

The thin lens;
Optical principles of the eye;
Diffraction grating.

This process has, of course, involved a very considerable amount of experimentation and the rejection of a number of experiments after a trial of one, two or three years. The foregoing list gives only the experiments which seem to be surviving this selective process. Most of them have already been incorporated into a lithographed supplement to the laboratory manual in use in our classes.

The approximately even division between the two types of experiment in the initial sequence has made it easy to prescribe the general content of the laboratory part of the intermediate one-semester course which had been proposed as a supplementary requirement for all who planned some advanced work in physics. It will consist primarily of the experiments which are being eliminated from the first-year course because of being too technical for that type of use.

But it is in the non-laboratory part of the first-year course that the greatest modifications have been made. A standard college-physics textbook still constitutes the nucleus of the course, but there is a very much larger body of "cytoplasm," so to speak, than characterizes the usual course in general physics. Extensive collateral reading of three types of material supplements the textbook and class work. One type is high-grade expository material exemplified by Mott-Smith's *This Mechanical World* (Appleton), Bragg's *Concerning the Nature of Things* (Century), Darwin's *New Conceptions of Matter* (Macmillan), and Andrade's *Mechanism of Nature* (Bell). The second type is historical material such as Chase's *History of Physics* (Van Nostrand), Lodge's *Pioneers of Science* (Macmillan), and Crew's *Rise of Modern Physics* (Williams and Wilkins). The third type provides an historico-philosophical approach to the logical foundations of physical science. It is based on Dampier's *Short History of Science* (Macmillan), the Columbia *Introduction to Reflective Thinking* (Houghton Mifflin), and Cunningham's *Problems of Philosophy* (Holt). Naturally this group of readings comes last. It furnishes the occasion for students to try their wings at broader generalizations than the usual science course provides, but on a more secure factual and historical basis than the customary course in philosophy can furnish.

The reading done on this outline covers a total of about three thousand pages if the basic textbook material be included. From Lodge, Dampier and Cunningham selections are made covering about half their content, but the remaining books are covered in their entirety. The reading is administered in the form of daily assignments and checked by a daily written quiz of fifteen minutes duration. The books are made available to students by being placed in quintuplicate on the reference shelves of the general library. The textbook is purchased by the student as usual.

The question will arise in the minds of many who find the available class time all too short to cover even the traditional range of material, how this greatly extended field can be adequately treated in class discussions, especially in view of the loss of one-third of the time to daily quizzes. The fact is that, at least as it has worked out in the experimental section of the present year, no revolutionary change in class

material has been involved. The students are, of course, encouraged to ask questions or initiate discussion on the collateral reading. The response is much more pronounced for the expository material of the first group of readings than for either of the other two. While this may be in part a consequence of the greater facility that a physics instructor possesses for eliciting discussion in this field, it seems to be at least equally a characteristic of the material. History is history, and after the various episodes have been recounted and interpreted by the different authors, little is left to be said.

More time is required for class consideration of the third group of references, however. The excursion into philosophy is, of course, scarcely deep enough to come to grips with the really overpowering monsters that inhabit that region. We see them at a distance, as it were, and learn the names and general natures of some of them. The attempt is made to put the student in a position to recognize such classical problems as the impact of mechanism upon teleology; to enable him to step with some assurance through the subtleties of the ancient paradox of scientific law *versus* human freedom of action; to recognize the microscopic abstractiveness of science and contrast it with the telescopic synthesis of philosophy; to distinguish between scientific determinism and philosophic determinism, and to relate the two to Heisenberg's principle of indeterminacy; to know the strong and weak points in the concept of causation and to see their bearing on statistical law; to detect the epistemology involved in our concepts of space and time; to realize the impossibility of escape from metaphysics of some kind, and that any act of decrying that discipline commits us *ipso facto* to another body of metaphysics that is the more insidious in that it is unrecognized. These ancient problems become less hazy when they are set against a background of experimental science than when they are prestidigitated out of thin air. It has been said that everyone should know enough philosophy to enable him to keep out of it. Perhaps it would be a little broader to say that every science student should know enough philosophy to enable him to orient his science in the intellectual enterprise as a whole. It is doubtful whether the traditional courses in philosophy can be relied upon to furnish this perspective. They are too introspective. They, like the rest of us, are prone to prepare budding specialists instead of following the advice of John Dewey. "Philosophy," said Dewey, "recovers itself when it ceases to be a device for dealing with the problems of philosophers and becomes a method, cultivated by philosophers, for dealing with the problems of men."

A rather limited experience indicates that provision can be made for a measurable acquaintance with these broad bases of scientific doctrine in the very body of scientific instruction itself, indeed rather more effectively than otherwise. When so treated, the time involved is not at all proportional to the ground covered, since in the main the process consists of summarizing from another point of view material already involved or implied in the traditional science course.

Perhaps it is carrying coals to Newcastle to state that one of the prerequisites of imparting a measure of breadth of intellectual interest to one's students is the possession of a much greater breadth on the part of the instructor himself. As a small boy replied when asked how he taught his dog so many tricks, "You see, you have to know more than the dog does." We like to think that teachers of physics are a rather highly selected group, in which case there should be no difficulty in preparing ourselves for a task of this kind. The literature is boundless, though highly repetitious. One can get a very respectable start in the history and philosophy of scientific doctrine within a few score volumes, though naturally the subject is not thereby exhausted. A suggested bibliography is appended, which makes no pretense at completeness. Indeed completeness in this field is scarcely attained in even a library catalog.

A host of minor problems attend this sort of venture. It is not the function of this paper to list them, much less to suggest solutions. Preliminary experience indicates that few of them will be found insoluble, at least in a liberal arts college with an administration which is sympathetic with the venture. One difficulty that up to the present has proved insurmountable so far as the writer is concerned is a reasonably

descriptive name for the type of course that has been outlined. "Arts physics" is pre-empted. "Cultural physics" seems a bit too naive. The adjective "pandemic" is being used by chemistry in a venture somewhat remotely analogous to this, but the connotation of world-wide disaster that clings to that word when used as a noun, contaminates it beyond the possibility of use in this connection. Other names have been suggested, none of which seem properly descriptive. Suggestions will be most thankfully received.[1]

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[1] Since the above was written, Professor T. D. Phillips, of Marietta College, has suggested the name "Natural Philosophy." The historical associations of this term commend it rather highly.

[2] Asterisks indicate some of the books which the writer has found the most stimulating for purposes of the present enterprise. This does not imply that the doctrines which they set forth are to be considered the most sound.

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ANY normal boy or girl of sixteen could master the calculus in half the time often devoted to stumbling through Book One of Caesar's Gallic War. And it does seem to some modern minds that Newton and Leibnitz were more inspiring leaders than Julius Caesar and his unimaginative lieutenant Titus Labienus.—E. T. BELL, in *The Queen of the Sciences.*

THEY that know the entire course of the development of science will, as a matter of course, judge more freely and more correctly of the significance of any present scientific movement than they, who limited in their views to the age in which their own lives have been spent, contemplate merely the momentary trend that the course of intellectual events takes at the present moment.—ERNST MACH in *Science of Mechanics.*

DEDICATORY Epistle to Richard Douglass Cox. Dear Sir: You have been with me constantly during the writing of these pages. In the approved fashion for those to whom books are dedicated, you have gone over the manuscript with your own hands—and sometimes with your feet. You have managed generally to maintain (on the minor scale appropriate to a minor work) that background of continuous catastrophe which the Thirty Years War made for Johann Kepler during the composition of his immortal treatise "On the Harmony of the World." Finally, in accepting the dedication of these pages, you have given me the opportunity to add to them what will be perhaps their most enduring feature; for, however physical theories may be transformed from time to time, the behavior of four-year-old brats will doubtless be the same for centuries, and generations of fathers will continue to remain to their offspring, as I now subscribe myself to you, Your obedient servant, RICHARD T. COX.—*Time, Space and Atoms.*

An International System of Physical Units and the Teaching of Such Units to American Students

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THIS paper is a plea for the exclusive use of the metric system in the teaching of all grades of physics, both basic and applied, throughout North America. In South America no such plea is needed.

It is generally agreed that in American secondary schools, colleges and universities, the advanced principles of basic physical sciences, such as light, heat, electricity and magnetism, are nearly always taught and studied in relation to units of metric measure. Consequently, no criticism is here offered against such teaching or study of advanced and basic physics. There are, however, other physical sciences, such as mechanics, acoustics and astronomy, which are often taught and studied in relation to nonmetric units, especially in their elementary stages, and in their applications to practice. It is here claimed that such nonmetric units lower the level of instruction by obscuring, complicating and confusing the subject. It is submitted that by adhering closely to metric units, the study of all physics is clarified, simplified, rendered more scientific and maintained on an international basis. It is also desirable to standardize internationally upon a single system of metric physical units.

METRIC MEASURES

In order to be specific, we may, for the purposes of present discussion, define the metric system as the decimal system of weights and measures (international in the sense of being in general use among many nations) that is based upon the international standard meter and standard kilogram, as preserved and maintained by the International Bureau of Weights and Measures at Sèvres. The metric system includes such decimal variants as the c.g.s., or *centimeter-gram-second*, system of units, and the *volt-ohm-ampere* series of practical electrical units, as adopted by various international scientific assemblies during the last fifty years. On the other hand, nonmetric measures may be defined as local national measures or systems of measures that are ordinarily nondecimal in their mutual relations. In practice, there are only two nonmetric systems of weights and measures of any importance as regards the study of physics; namely, the British system and the American system. These are by no means identical, but have much in common.

SINGLE-UNIT CHARACTER OF A DECIMAL SERIES

It may be claimed, and is generally admitted, that any decimal series of units, such as the American and Canadian decimal currency units —*dollar*, *dime*, *cent* and *mill*—are not four different units, but present a single unit—the *dollar*—and three subdecimal parts of the same. These may be properly regarded as the *decime* of the dollar, the *cent* of the dollar and the *mill* of the dollar, respectively. In the same way, the series of metric lengths—*kilometer*, *hectometer*, *decameter*, *meter*, *decimeter*, *centimeter*, and *millimeter*—do not connote seven different units, but one unit—the *meter*—and six decimal multiples or submultiples of the same. The unabridged statement of the list would be *one thousand meters*, *one hundred meters*, *ten meters*, *one meter*, *one-tenth meter*, etc.

In contrast to the single-unit character of a decimal series, stands the multiple-unit character of any nondecimal series of units. Thus, the American arithmetical table of Long Measure contains the following nondecimal units: *inch*, *surveyor's link*, *foot*, *yard*, *fathom*, *pole*, *surveyor's chain*, *furlong*, *statute mile*, and *nautical mile*. Although only four of these, the *inch*, *foot*, *yard* and *mile*, are in ordinary everyday use, yet

even these four make a relatively complex system that is difficult for non-English speaking people to understand, and all ten have usually to be memorized at school. British arithmetical tables of Long Measure commonly add to the preceding list the *hand* and the *league*. Such tables occasionally also add the *barleycorn*, *palm*, *span* and *bolt* (of cloth).

The result of all these nondecimal Anglo-American units is that, whereas in the metric system there are only three[1] units—the *meter*, *liter* and *gram*, in the American system there are some fifty units, and in the British system there are some sixty. In the arithmetic books of the numerous metric countries, there are either no tables of weights and measures, or else a single table of the kilo-to-milli prefixes. In the arithmetic books of the English-speaking peoples, there are some nine or ten tables to be learned at school. Moreover, between the fifty-odd American units and the sixty-odd British units, there are thirteen having the same name, but differing in magnitude, either between the different tables, or between corresponding tables of Great Britain and America. These ambiguous units are the *drachm*, *scruple*, *ounce*, *pound*, *hundredweight*, *ton*, *peck*, *bushel*, *gill*, *pint*, *quart*, *gallon* and *barrel*. The most serious offenders in ambiguity are probably the *gill*, *pint*, *quart* and *gallon* of liquid measure. In the British Empire, these are severally over twenty percent larger than in the United States: for instance, on the south shore of Lake Erie, a *liquid quart* is 0.94636 liter, but on the north shore, or Canadian side, it is 1.1365 liters.

So manifest is the contrast between the simplicity and precision of the metric system and the ambiguity of nonmetric systems for the teaching of physics, that physics teachers would probably have decided to teach all branches of physics exclusively in the metric system, if certain objections to the more extended use of the metric system had not been current among them. We may briefly examine these objections, so far as the writer has been able to locate them.

(a) *That the metric system should be discouraged, because it is a decimal system, and that a duodecimal system, admitting of more numerous numerical factors (2, 3, 4 and 6, as against only 2 and 5) would be better.* To this it may be replied that, although theoretically 12 has advantages over 10 as an arithmetical base, yet all the world uses the base 10 and decimal arithmetic; nor is there any hope of world-wide arithmetical reform in this respect. Moreover, in the absence of experience with duodecimal arithmetic, it is uncertain whether the advantage of increased factoring would outweigh the disadvantage of a more complicated arithmetic. For instance, we should have to learn and remember that the numerical expressions 10, 100, 1000, etc., which now denote the numbers ten, one hundred and one thousand, would, on the duodecimal base, mean and represent what we now write as 12, 144 and 1728.

(b) *That the meter is not a precise decimal fraction of our earth's quadrant but is an arbitrary unit of length.* There can be no question that the meter was not selected arbitrarily, in the sense of a random choice. It was selected to be, as nearly as could be measured, the ten-millionth part of the earth's northern quadrant through Paris. Geodetic measurements were made over that portion of the meridian which lies between Dunkirk, in France, and Barcelona, in Spain, during the period 1791 to 1799. It was agreed by an international committee that the standard meter thus derived should not be considered as subject to amendment or modification in the light of subsequent and probably more precise redeterminations. The most recent measures are stated to indicate that the standard meter is shorter than the theoretical ten-millionth of a quadrant by one part[2] in five thousand. In other words, the standard meter is approximately 0.2 mm too short. With reference to modern geodetic precision, this would be a considerable error; but at the date of executing the original meter bar, near the end of the eighteenth century, it would be regarded as a small error. For purposes of computation, the correction of 1.000229 is readily applied; but for practical chart work, the discrepancy is trivial at the present time. A large map, say one meter square, accurately engraved, would be 0.2 mm short in length and breadth, considered as a decimal representation of a small area on the earth; but casual changes in its dimensions with climatic variations of temperature and moisture would probably be considerably greater than this error in the scale.

(c) *That the kilogram does not strictly represent the mass of a cubic decimeter of pure water under standard specifications; and that hence the metric system is invalidated.* An

[1] The question is sometimes raised whether the *nautical mile*, as an international unit of length at sea, does not introduce an extra and a non-decimal unit of length into the metric system. An answer is that in the complete metric system, angles are decimal and not sexagesimal, commencing with the quadrant of 100 *grads*, each subdecimalized. On that basis, the decimal minute or *centrigrad* of arc is the 1/10,000 of the quadrant, or 1 km, whereas the duodecimal minute of arc, being 1/5400 quadrant, is 1.853 km, approximately the length of the *nautical mile*. Decimal angles are used to some extent in France, as well as transits and theodolites with 400 grads to the circle.

[2] *Annuaire pour l'an 1932*, Bureau de Longitudes, Paris, p. 145.

answer to this objection is that the kilogram standard was constructed to have the mass of a cubic decimeter of pure water at the temperature of 4°C and the pressure of 760 mm of mercury. More recent measurements[3] are stated to indicate that the standard kilogram represents 1.000027 dm,[3] under those specifications, or its water volume is in excess by about 27 parts per million. It is generally admitted that the discrepancy is remarkably small, in view of the date of the measurement. For all ordinary scientific volumetric purposes, the error may be neglected; but the correction factor can, when necessary, be applied. Moreover, without altering the mass of the standard kilogram, the error could be eliminated, if it were so internationally desired, by altering the specification of the pressure. If the kilogram of water were subjected to a pressure of about 1.5 atmospheres, it would occupy the specified cubic decimeter of volume.

(d) *That the metric system is unsuitable for practical use in English-speaking countries.* An answer to this charge is contained in the science, art, industry and business of spectacle-lens production. Until about the end of the last century, spectacle lenses in America were prescribed, ground, polished, adjusted and sold in the customary inch system of measures. In more recent years, all these operations have been, and now are, regularly carried out in the metric system. The oculist or optometrist measures the lenticular needs of the eye in *diopters*, and prescribes the glasses required in these metric terms. The optician grinds and polishes the glasses accordingly, measuring, fitting and adjusting them to metric measure. This is not only a simpler procedure to follow but it is also international, and prescriptions made in one country can now ordinarily be worked out in any other. The change in this industry from nonmetric to metric units was effected without governmental edict or control and entirely by conventional agreement.

(e) *That the general introduction of the metric system into America must be impracticable, because of the consequent necessity of discarding a large part of the existing installed machinery.* To this it may be answered that the metric system is an improved means of measuring, specifying and computing dimensions, and not necessarily a standard for manufacturing. In no country is it compulsory to use metric gauges, drawings or tools in factories. It is only compulsory to buy and sell by the meter and gram. Inspectors visit stores and markets, not factories or assembling plants. Purchase and sale of goods are matters of public and even of international interest, whereas manufacture is a matter of private concern. If America adopted the metric system officially, it is only reasonable to suppose that the goods that are made today would continue to be made from the same drawings and with the same tools, but that the sales would be made according to revised catalogs with prices based on the meter and gram. There would be public inconvenience at the outset in learning the new catalogs and prices but the change should not materially affect the factories, at least until the old drawings and tools had worn out and had to be replaced. Moreover, the experiences of a number of European countries that have changed to the metric system during the last half century do not indicate serious expenses due to discarding of machinery. Japan, for example, is now in process of changing over to the metric system, and the writer, during a recent visit, was unable to discover complaints owing to discarding of original machinery, mostly built in English-speaking countries. It is also well-known that American standard tools have for many years been exported to metric countries, which does not suggest their incapacity for use in production for sales in meters and grams. Many such American tools can be seen abroad today in metric countries.

[3] *Smithsonian Physical Tables*, 6th edition, p. 6.

Steady Infiltration of the Metric System into America

It is believed that a careful examination of the present and recent status of measures in America will show that this country is in steady process of transition to the eventual complete adoption of the metric system, although it is not possible to predict the final official date of acceptance. In the Anglo-Saxon countries such reforms have usually been very gradual. It is reported in Ball's *History of Mathematics* that the process of complete adoption of the Arabic system of numerals in the business world, after that system had been accepted by the scientific world, occupied, in England, about 150 years. During that time, merchants' accounts were kept in the system of Roman numerals. The change was slowly effected in the face of strong opposition. At the present date there are vestiges of the Roman system of numerals on the faces of clocks, on the bindings of books and in the dates engraved on public buildings. Again, the transition from the Julian to the Gregorian calendar, which was made in nearly all western continental Europe in 1582, was not effected in Great Britain and America until 1752. Taking the start of the metric system, in France, as 1800, and estimating according to the incubation period of Arabic numeral reform, we might hazard the date of metric reform with us as, say, 1950; whereas, according to experience in calendar reform, it might be 1970. In any case, however, such reforms advance very slowly in democratic countries, which is perhaps a wholesome safeguard against hastily unwise action.

Meanwhile, the use of the *meter* and *gram* goes slowly but steadily forward among us. Electric energy is bought and sold exclusively

in *kilowatt-hours*, and the *kilowatt* is a metric unit of power. All of the international practical units—*volt*, *ohm*, *ampere*, *farad*, *coulomb* and *henry*—are metric units. Some of these are firmly rooted in common speech. Radio-broadcasting has made us familiar with *meter wavelengths*. Moving-picture photographic films are sold here on a millimeter-width basis. Each five-cent nickel coin, when fresh from the mint, weighs 5 g, and subsidiary silver coin (50-cent, 25-cent, and 10-cent pieces), weigh at the rate of 25 g to the dollar. On the other hand, our bronze coins still remain nonmetric; each cent piece, or "penny," weighs 2 dwt, or 48 grains troy (3.11 g).

Within recent months, the Amateur Athletic Union has announced its decision to use metric measures exclusively in all official American track and field events.[4] A.A.U. swimming distances are still nonmetric, apparently because indoor swimming tanks are constructed, at present, to conform with one hundred yards as the standard of distance. Perhaps such tanks will be built in the future with the slight extra length needed to fit metric records. Otherwise, American swimmers will be prevented from qualifying for world records except during Olympic races, once every four years.

If, then, North America is actually in process of slow transition to the metric system for general use, as seems reasonable from the foregoing considerations, it is all the more appropriate that the subject of physics should be taught entirely in metric terms. Nevertheless, in giving out daily problems for quantitative solution, it is reasonable that at least a certain part of them should be formulated in nonmetric customary units, both as to questions and answers, in order to familiarize the students with mental transition from one system to the other and to avoid the danger of an academic insulation of the subject. According to the writer's experience, it is ordinarily much easier and swifter to solve such vernacular problems in three steps: (a) recast the problem into metric terms, (b) compute the solution, and (c) recast the metric solution back into vernacular terms. The quantitative language of modern science is essentially metric, and it is psychologically economical to conduct trains of physical thought in physical language. But physicists have to be ready to solve a practical problem at any time from vernacular data, without reference to conversion tables. This familiarity with both unscientific and scientific units will probably continue to be necessary with physicists, diminishingly, for years after the advent of the metric system into general national affairs.

In reading scientific papers and communications published in physical journals, it is astonishing to see the incongruous association of units frequently employed by some of our leading physicists. On the same page, and sometimes in the same sentence, there will be both scientific and unscientific units, both metric and nonmetric. This incongruity is not surprising when we remember that in different parts of a scientific presentation, the physicist will be likely to draw alternately on his scientific memory for metric details, and upon his vernacular memory for subsidiary elements. When these passages are perused, say one hundred years hence, by the generation of American physicists of that day, it is quite likely that the association of scientific and unscientific units will sound quaint and archaic. Effort should be made to use scientific units in all our scientific work, if only for the sake of consistency. Many physicists defend themselves in such practices by claiming that if they used metric units throughout their discourses, their audiences would not understand or follow them. The metricists retort, however, that this is but a cloak for laziness in thought and expression; all hearers of sufficient intelligence to follow even an elementary scientific disquisition, must already know the elements of the metric system, and therefore can understand the statements more readily in terms of the simple *meter* and *gram* than in terms of the multiple-unit tables of our inheritance. A careful inspection of current American literature of today, as compared with corresponding literature of, say, forty years ago, will probably convince an unprejudiced enquirer that the use of metric terms as accepted vehicles of expression is much more general than formerly. Forty years ago, if a writer referred to "a kilometer," he would

[4] *The Metric System in Track and Field Events*, Sci. Mo. **36**, 385–386 (1933).

be likely to follow it with a parenthetical explanation, such as (0.621376 mile), to, say, six-digit precision, when the original quotation may have been left indefinite to perhaps ten or even twenty percent. Nowadays, the quotation of "a kilometer" is commonly followed by no explanation, as being self-sufficient.

With so many of the civilized nations of the earth already wedded to the complete adoption of the metric system, and to the exclusion of their original primitive systems, it is only a question of time when free play of modern intercommunication will enforce the metric system here. It is generally agreed that the propagation-velocity of electromagnetic disturbances in free space is the same as that of light; that is, very nearly 3×10^5 km/sec. Since the length of a complete great circle of our globe, passing through the poles, is very nearly 4×10^4 km, this propagation velocity would carry an electromagnetic impulse 7.5 times around the globe in one second of time, or to the antipodes of any locality in 1/15 sec. Because of the effects of attenuation, and also probably to successive reflections between the earth's surface and the ionized layers in the upper atmosphere, the group velocity of radio-signalling waves, as thus far measured over long distances, seems to be appreciably less than the free propagation velocity, and is perhaps only about 2.5×10^5 km/sec.; but even so, the time of radio transit to the antipodes of any place is only about 0.08 sec., so that our planet has shrunk recently to 8 centiseconds of maximum separation by radio. The prospect of maintaining indefinitely more than one system of weights and measures on an 8-centisecond planet is surely very small? Will then the supervening single system be the 60-unit British system, the 50-unit American system, or the 3-unit metric system?

What is the Best System of Units for the Physical Sciences?

As we all know, physical science employs, in all countries, units of measurement that are based on the international *meter* and international *kilogram*. There are, however, various subsystems of these metric physical units, and there is room for international standardization in this respect. Most textbooks on physics are unitologically based upon the c.g.s. system, which was adopted in 1873 by the *Committee for the Selection and Nomenclature of Dynamical and Electrical Units* of the British Association for the Advancement of Science. As is well known, this classical c.g.s. system is single and unique, except in relation to electrics and magnetics, because it employs (1) an electric subsystem, based on the mechanical forces exerted between electric charges in free space, and (2) a magnetic subsystem, based on the mechanical forces exerted between magnetic poles in free space. Sometimes researches employ one of these two subsystems, and sometimes the other, so that a competent reader must be acquainted with both. Then there is (3) the Heaviside-Lorentz c.g.s. system, which is "rationalized," or has the constant 4π excluded from formulas dealing with rectilinear configurations, and inserted in formulas dealing with spherical configurations. It also simplifies many electric and magnetic working formulas. This system is much used by writers on theoretical physics. Theoretical physicists also employ (4) the Gaussian c.g.s. system, for which certain advantages may be claimed. Then there is (5) the universally employed series of "practical" international magnetic units—the *volt*, *ohm*, *ampere*, *coulomb*, *farad*, *henry*, *joule* and *watt*—all based upon the c.g.s. magnetic system, and connected with it by a corresponding series of decimal multiples (10^8, 10^9, 10^{-1}, 10^{-1}, 10^{-9}, 10^9, 10^7 and 10^7). International standards are constructed in this series, and all physicists conduct measurements in terms of them. Finally, because there are certain admitted small errors in the magnitudes of these international standards, with reference to the theoretical basic c.g.s. magnetic units, physicists recognize a slightly modified, or corrected, series, sometimes called the *absolute practical* series, in which there would be the "*true ohm*," the "*true volt*," etc. The exact magnitudes of these standards cannot, of course, be known; but as time goes on, and the precision of measurements improves, the numerical correction factors become more definitely recognized. Thus, at the present time, the Bureau of Standards' estimates of these correc-

tion factors, for the particular cases of the volt, ohm, ampere and watt, are:[5]

International volt = 1.00043 true volts,
International ohm = 1.00052 true ohms,
International ampere = 0.99991 true ampere,
International watt = 1.00034 true watts,

and so on for other international units. Some claim that these absolute practical units thus form part of another, a sixth system, with which well-informed physicists have in these days to be familiar. That is a question for debate; but at least these correction factors form a series which cannot be ignored by physicists when electrical measurements of the highest precision are made in the laboratory.

These five or six systems of scientific units, to say nothing of the gravitational systems, with the *foot-pound*, and *kilogram-meter*, lay an undue burden on teachers and students of physics. In addition, physicists in America lay an extra burden on their coworkers in non-English speaking countries when they introduce units from the vernacular into their scientific papers. In the interests of clearness and simplicity, a concerted effort should be made to work towards an international single and comprehensive system of units and the relinquishment of all the others. Such a possible universal system was proposed by the Italian physicist Giorgi in 1901. This system has been endorsed by leading unitologists in a number of countries, and does not seem to have raised serious objections in any, unless the departure of unit density from the density of water is so interpreted.

The Giorgi Proposed Comprehensive System of Practical and Physical Units

The Giorgi system adopts and includes the eight units in the practical series (*volt*, *ohm*, *ampere*, etc.) and builds this series into a completely comprehensive system by adopting the international *meter* as the unit of length, the international *kilogram* as the unit of mass, and the international mean solar *second* as the unit of time. These conditions satisfy the *joule* and *watt;* because the *vis viva* (Mv^2) of 1 kg, moving with a speed of 1 m/sec., is just 1 j. Except that unit density would be 1 kg/m^3, which is 10^{-3} g/cm^3, every important physical unit seems to fit into the system fairly well. A table of specific gravities would, of course, be the same in the Giorgi system as in the c.g.s. system. All electrical measurements and standards would remain as they are now; but the units of gradient, area and volume, such as *volts per meter*, *amperes per square meter* and *joules per cubic meter*, would be decimally altered from their counterparts in the c.g.s. system. There would cease to be a duality as regards electric and magnetic units, all units being in the present practical magnetic series; that is, there would be no separate set of electric units. Although there would be no necessity to abandon the c.g.s. systems if the Giorgi system were completed and internationally adopted, yet it would probably happen that the c.g.s. systems would gradually go into desuetude. Before that could come about, however, the magnitudes of a large number of physical units now applied in the c.g.s. system would have to be decimally altered, and tables of such units correspondingly modified, all of which would require time and mutual consent. If and when, however, such a system became generally adopted, the need for learning any other system of units than the Giorgi system should disappear in commerce as well as in science. This is an ultimate goal so earnestly to be desired that the merits of the Giorgi system should be carefully studied by all students of science and world affairs.

Dellinger-Bennett-Karapetoff-Mie System

There is one other proposed comprehensive system of units which may claim to be considered as an alternative for the Giorgi system. It was suggested by several different writers independently and has been referred to by some persons as the c.g.s.s., or *centimeter-gram-seven-second*, system. It proposes to adopt and include all the existing practical units as constituent elements, like the Giorgi system, but to use the *centimeter* as the unit of length, the *gram-seven* (10^7 g or 10 metric tons) as the unit of mass, and the *mean solar second* as the unit of time. The *joule* and *watt* are complied with, since the *vis viva* of 10^7 g moving with a speed of 1 cm/sec. is 1 j. In other respects, the system would run parallel to the Giorgi system. The unit of area would be the *square centimeter* and that of volume would be the *cubic centimeter*. Physicists accustomed to the use of the c.g.s. system would probably find these units more convenient than the *square meter*

[5] E. C. Crittenden, *Present Status of the International Electrical Units*, Trans. A. I. E. E. (1927), p. 990.

TABLE I. *Fundamental c.g.s. units and three derived "practical" systems.*

Quantity	Symbol	Fundamental c.g.s.	← Practical					→
			q.e.s. Maxwell (1881)	In c.g.s. Units	m.k.s. Giorgi (1901)	In c.g.s. Units	c.g.s.s. Dellinger-Bennett	In c.g.s. Units
Mechanic								
Length	L	*cm*	quadrant	10^9	*meter*	10^2	*cm*	1
Mass	M	*g*	eleventh-g	10^{-11}	*kilogram*	10^3	g-seven	10^7
Time	T	*second*	second	1	*second*	1	*second*	1
Area	S	cm^2	sq. quad.	10^{18}	m^2	10^4	cm^2	1
Volume	V	cm^3	cubic quad.	10^{27}	m^3	10^6	cm^3	1
Density	d or ρ	g/cm^3	eleventh g/quad.^{3}	10^{-33}	kg/m^3	10^{-3}	g-seven/cm^3	10^7
Velocity	v	$cm/sec.$	quad./sec.	10^9	$m/sec.$	10^2	$cm/sec.$	1
Acceleration	a	$cm/sec.^2$	quad./sec.^{2}	10^9	$m/sec.^2$	10^2	$cm/sec.^2$	1
Force	F	*dyne*	centidyne	10^{-2}	dyne-five	10^5	dyne-seven	10^7
Pressure	p	*dyne/sq. cm*	cntdyne/sq. quad.	10^{-20}	dyne-5/sq. *m*	10	dyne-7/sq. cm.	10^7
Torque	Q	*dyne⊥ cm*	cntdyne⊥ quad.	10^7	dyne-5⊥ *m*	10^7	dyne-7⊥ cm	10^7
Moment of inertia	J	$g\text{-}cm^2$	11th-g-quad.^{2}	10^7	$kg\text{-}m^2$	10^7	$g\text{-}cm^2$	1
Energetic								
Work	W	*erg*	*joule*	10^7	*joule*	10^7	*joule*	10^7
Power	P	*erg/sec.*	*watt*	10^7	*watt*	10^7	*watt*	10^7
Thermal								
Heat	H	*g-calory*	11th-g-cal.	10^{-11}	*kg-calory*	10^3	*g-calory*	1
Temperature	t or T	*deg. C. or abs.*	*deg. C. or abs.*	1	*deg. C. or abs.*	1	*deg. C. or abs.*	1
Luminous								
Flux	F	*lumen*	*lumen*	1	*lumen*	1	*lumen*	1
Illumination	E	*phot*	lumen/quad.^{2}	10^{-18}	*lux*, lumen/m^2	10^{-4}	*phot*	1
Intensity	I	*int. candle*	*int. candle*	1	*int. candle*	1	*int. candle*	1
Brightness	B	candles/cm^2	candles/quad.^{2}	10^{-18}	candles/m^2	10^{-4}	candles/cm^2	1
Focal power		cm^{-1}	quad.$^{-1}$	10^{-9}	*diopter*	10^{-2}	cm^{-1}	1
Electric								
Electromotive force	E	abvolt	*volt*	10^8	*volt*	10^8	*volt*	10^8
El: field intensity	ϵ or V	abvolt/cm	volt/quad.	10^{-1}	volt/m	10^{-2}	volt/cm	10^6
Resistance	R	abohm	*ohm*	10^9	*ohm*	10^9	*ohm*	10^9
Resistivity	ρ	abohm-cm	ohm-quad.	10^{18}	ohm-m	10^{11}	ohm-cm	10^9
Current	I	abampere	*ampere*	10^{-1}	*ampere*	10^{-1}	*ampere*	10^{-1}
Current density	i	abamp/cm^2	mp./sq. quad.	10^{-19}	amp./sq. m	10^{-5}	amp./sq. cm	10^{-1}
Conductance	G	abmho	mho	10^{-9}	mho	10^{-9}	mho	10^{-9}
Conductivity	γ	abmho/cm	mho/quad.	10^{-18}	mho/m	10^{-11}	mho/cm	10^{-9}
El: quantity	Q	abcoulomb	*coulomb*	10^{-1}	*coulomb*	10^{-1}	*coulomb*	10^{-1}
El: displacement	D	abcoulomb/cm^2	coulomb/quad.^{2}	10^{-19}	coulomb/m^2	10^{-5}	coulomb/cm^2	10^{-1}
Capacitance	C	abfarad	*farad*	10^{-9}	*farad*	10^{-9}	*farad*	10^{-9}
Permittivity	κ_0	(abfarad/cm) = 1	farad/quad. =	$\frac{1}{4\pi v^2}$	farad/m =	$\frac{10^7}{4\pi v^2}$	farad/cm =	$\frac{10^9}{4\pi v^2}$
Frequency	f	cycle/sec.	cycle/sec.	1	cycle/sec.	1	cycle/sec.	1
Magnetic								
Magnetomotive force	$\mathcal{F}$	gilbert	*amp.-turn*	$\frac{4\pi}{10}$	*amp.-turn*	$\frac{4\pi}{10}$	*amp.-turn*	$\frac{4\pi}{10}$
Mag: field intensty	H	gilbert/cm	amp-turn/quad.	$4\pi/10^{10}$	amp-turn/m	$4\pi/10^3$	amp-turn/cm	$4\pi/10$
Space permeability	μ_0	abhenry/cm	henry/quad.	$1/4\pi$	henry/m	$10^7/4\pi$	henry/cm	$10^9/4\pi$
Magnetic flux	Φ	*maxwell*	volt-second	10^8	volt-second	10^8	volt-second	10^8
Mag. flux density	B	maxwell/cm^2	volt-sec./quad.^{2}	10^{-10}	volt-sec./m^2	10^4	volt-sec./cm^2	10^8
Permeance	$\mathcal{P}$		henry	$10^9/4\pi$	henry	$10^9/4\pi$	henry	$10^9/4\pi$
Reluctance	$\mathcal{R}$		yrneh	$4\pi/10^9$	yrneh	$4\pi/10^9$	yrneh	$4\pi/10^9$
Inductance	L	abhenry	*henry*	10^9	*henry*	10^9	*henry*	10^9
Magnetization	I		volt-sec./quad.^{2}	$10^{-10}/4\pi$	volt-sec./m^2	$10^4/4\pi$	volt-sec./cm^2	$10^8/4\pi$
Magnetic pole	m	maxwell/4π	volt-sec.	$10^8/4\pi$	volt-sec.	$10^8/4\pi$	volt-sec.	$10^8/4\pi$
Chemical								
Electrochemical equivalent		g/abcoulomb	11th-g/coulomb	10^{10}	kg/coulomb	10^{-4}	g-seven/coulomb	10^{-8}

and *cubic meter* of the Giorgi system. On the other hand, the *centimeter* is not so desirable a fundamental unit of length as the *meter*, and 10^7 g is a very large and awkward size and name for a fundamental scientific unit of mass. In the opinion of the writer, the *meter* and *kilogram* are much more desirable as fundamental units than the *centimeter* and *gram-seven;* but because at least one textbook[6] has been published in the c.g.s.s. system of units, it seems only fair to present it for consideration along with the Giorgi system, in which apparently no books, but only individual papers, have thus far been printed.

[6] See Bibliography, No. 8.

One question would have to be decided before either the Giorgi or the c.g.s.s. system could be adopted internationally: namely, whether the unit of magnetomotive force should be the *ampere-turn* or the 4πth part of one *ampere-turn*. This raises the question of so-called "rationalization" and affects several other practical units, not thus far settled upon. If the unit of magnetomotive force were made the *ampere-turn*, the logical effect would be to identify the strength m of a magnetic pole with the amount of magnetic flux Φ emerging from it, and also the quantity q of an electric charge with the electric flux emerging from it, thus identifying electric flux and displacement. Various other simplifications would be effected.

Thus, the specific tractive force between opposed parallel pole-surfaces carrying uniform flux density B would be $B^2/2\mu_0$ instead of $B^2/8\pi\mu_0$, where μ_0 is the space permeability. Also, magnetic volume energy would be $B^2/2\mu$ instead of $B^2/8\pi\mu$, where μ is the permeability of the medium. Again, the hysteretic work, per unit of volume and per cycle, of a magnetic substance subjected to uniform cyclic magnetization would be equal to the area of the Ewing loop in HB units, instead of being $HB/4\pi$. In electrostatic formulas, like simplifications would occur.

Table I lists 45 quantities in the c.g.s. magnetic system, and also in the only three practical systems that present themselves for consideration (all here rationalized). The first is the q.e.s., or *quadrant-eleventh-gram-second*, system, discovered by Maxwell. The second is the m.k.s. system, and the third is the c.g.s.s. system. The *quadrant* (10^7 m) is so great a unit of length, that no one has seriously proposed the practical adoption of the q.e.s. system. In order, therefore, to complete the existing practical series of units into a complete practical system, choice seems to lie between the m.k.s. and c.g.s.s. systems. For general scientific work, it would seem that the m.k.s. system has the advantage. It would be a great misfortune if electrophysicists and electrotechnicians adopted a practical system that physicists and technicians in other branches of science found themselves unable to accept.

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HUMAN happiness depends chiefly upon having some object to pursue, and upon the vigor with which our faculties are exerted in the pursuit.—JOSEPH PRIESTLEY, in the preface to *History of Electricity.*

IT is commonly said that P. G. Tait laid down the length of a drive on mathematical principles which could not be exceeded, and that his son drove the ball farther. But at that time Tait had not realized the full effect of spin on the ball.—SIR OLIVER LODGE, in *Past Years, An Autobiography.* Young Tait was a golf champion.

A Glossary of German-English Equivalents Relating to Atomic Structure

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THE following vocabulary has been prepared for ultimate incorporation in Patterson's *German-English Dictionary for Chemists*. It makes no claims to completeness but is offered in its present form for whatever it may be worth to those who are interested. The compilers are indebted to Dr. Geo. L. Clark, University of Illinois, Dr. A. Landé, Ohio State University, and Dr. W. A. Noyes, Jr., Brown University, for criticisms and suggestions.

abbremsen, *v.t.* check, retard.
abklingen, *v.i.* die away.
abschattieren, *v.t.* & *i.* shade off.
Abschirmungszahl, *f.* screening number, screening constant.
Achterschale, *f.* shell of eight electrons, octet shell.
Achtzehnerperiode, *f.* period of eighteen.
Anfangsbahn, *f.* initial orbit or path.
Anfangsniveau, *n.* initial level.
anklingen, *v.i.* grow stronger, increase.
anregbar, *a.* capable of being excited.
anregen, *v.t.* excite.
Anregungsgrenze, *f.* excitation limit.
Anregungspotential, *n.* **Anregungsspannung,** *f.* excitation potential.
Anregungsstärke, *f.* strength of excitation.
Anregungswahrscheinlichkeit, *f.* probability of excitation.
antistokessch, *a.* anti-Stokes.
Aphelabstand, *m.* aphelion distance.
Arbeitsaufwand, *m.* expenditure of work.
atomar, *a.* atomic.
Atomhülle, *f.* atomic shell.
Atomkern, *m.* atomic nucleus.
Atommechanik, *f.* mechanics of the atom.
Atomnummer, *f.* atomic number.
Atomrest, *m.* atomic residue (=Atomrumpf).
Atomrumpf, *m.* kernel or core of the atom (the atom minus the outer electrons).
atomtheoretisch, *a.* of or according to the atomic theory.
Atomzahl, *f.* atomic number; number of atoms.
Aufbauprinzip, *n.* construction principle (governing the structure of atoms).
Aufelektron, *n.* outer electron, valence electron.
Auffänger, *m.* collector.
Aufprall, *m.* impact.
Ausgangsgleichung, *f.* initial equation, starting equation.
Ausgangsniveau, *n.* initial level.
ausharren, *v.i.* persist.—**ausharrend,** *p.a.* persistent.
Ausläufer, *m.* (*Spect.*) attendant line, satellite.
ausleuchten, *v.t.* extinguish.—*v.i. and r.* cease giving light.
Aussenelektron, *n.* outer electron.
Aussenseite, *f.* outer side, outside.
Auswahlprinzip, *n.* selection principle.
Auswahlregel, *f.* selection rule.
Bahn, *f.* orbit; path.
Bahnebene, *f.* orbital plane.
Bahnschleife, *f.* orbital loop.
Bahnschlinge, *f.* orbital loop.
Bahnübergang, *m.* orbital transition.
Bandenlinie, *f.* band line.
Bandkante, *f.* edge of a band, band head.
Besetzungszahl, *f.* number of electrons in a completed shell.
Bezugslinie, *f.* reference line.
Bezugswert, *m.* reference value.
Bindeelektron, *n.* binding electron, valence electron.
blauverschoben, *p.a.* displaced toward the blue.
bremsen, *v.t.* check, retard, brake.
Bremsstrahlen, *f.pl.* rays due to retarding of particles.
Bremsstrahlung, *f.* radiation due to retarding of particles (usually continuous radiation).
Bremsung, *f.* checking, retarding.
Brennlinie, *f.* focal line.
Büschel, *m.* bundle, pencil.
Doppelwurzel, *f.* (*Math.*) double root.
Drehimpuls, *m.* angular momentum, moment of momentum.
Drehsinn, *m.* direction of rotation.
Drehvektor, *m.* rotation vector.
Dreiergruppe, *f.* group of three, 3-group.
Dreierstoss, *m.* three-body collision.
dreiquantig, *a.* of three quanta, 3-quantum.
Dublett, *n.* doublet.
durchqueren, *v.t.* traverse, cross.
Eichgas, *n.* standard gas.
Eichkurve, *f.* calibration curve.
Eichpunkt, *m.* reference point.
Eichwert, *m.* reference value, standard value.
Eigendrehimpuls, *m.* proper (or characteristic) angular momentum.
Eigenfrequenz, *f.* proper (or characteristic) frequency.
Eigenfunktion, *f.* proper function, characteristic function, "eigenfunktion."
Eigenschwingung, *f.* proper or characteristic vibration.
Eigenstrahlung, *f.* proper or characteristic radiation.
Eigenwert, *m.* proper value, characteristic value, "eigenwert."
Eigenzustand, *m.* proper or characteristic state.
Einfallsstrahl, *m.* incident ray.
einfangen, *v.t.* capture, catch, seize.
Einfangung, *f.* capture (of an electron).
Einlinienspektrum, *n.* spectrum of single lines.
einquantig, *a.* of one quantum, 1-quantum.
einstrahlen, *v.t.* radiate upon, irradiate.
Einstrahlung, *f.* radiation taken in, (loosely) absorption; irradiation.
Elektronenbahn, *f.* electronic path or orbit.
Elektronendrall, *m.* electron spin.
Elektronenhülle, *f.* electronic shell.
Elektronenstoss, *m.* electronic collision or impact.
Elektronenzahl, *f.* number of electrons.
Ellipsenbahn, *f.* elliptic orbit.
Endbahn, *f.* final path or orbit.
Endniveau, *n.* final level.
Endquantenzahl, *f.* final quantum number.
Endterm, *m.* final term.
Energieniveau, *n.* energy level.
Energiequant, -quantum, *n.* energy quantum.
Energiequantelung, *f.* energy quantization.
Energiestufe, *f.* energy step or stage, energy level.
entartet, *p.a.* degenerate.
entarten, *v.t.* render degenerate.
Entartung, *f.* degeneration.
Erregerlinie, *f.* exciting line.
Ersatzelektron, *n.* equivalent or replacing electron.
extrapolatorisch, *a.* pertaining to extrapolation.—*adv.* by extrapolation.
Faradaykäfig, *m.* Faraday cage.
Feinaufspaltung, *f.* fine separation.
Feinstruktur, *f.* fine structure.
Feinverschiebung, *f.* fine displacement.
feldfrei, *a.* field-free.
Flächensatz, *m.* theorem of conservation of areas.
flächenzentriert, *a.* face-centered.
Frequenzwert, *m.* frequency value, frequency.
Füllflüssigkeit, *f.* (*Micros.*, etc.) immersion liquid.
gaskinetisch, *a.* pertaining to the kinetics of gases.
gitterfremd, *a.* (*Cryst.*) foreign to the lattice.
Gitterkonstante, *f.* lattice constant; grating constant.
Gittertypus, *m.* lattice type.
Gliednummer, *f.* number of a member (in a series).
Glimmentladung, *f.* glow discharge.
Glühdraht, *m.* glowing wire, hot wire.
grobmechanisch, *a.* macromechanical, large-scale.
Grundbahn, *f.* ground orbit.
Grundgleichung, *f.* fundamental equation.
Grundniveau, *n.* ground level.
Gruppengeschwindigkeit, *f.* group velocity.
Halbwertdruck, *m.* half-value pressure.
Halbwertsbreite, *f.* width at half of maximum intensity (of a spectral line or band).
Halbwertzeit, *f.* half-life period.
halbzahlig, *a.* half-integral.
Härtemesser, *m.* hardness gage.
Hauptlinie, *f.* principal line.
Hauptquantenzahl, *f.* principal or total quantum number.
Hauptschwingung, *f.* principal vibration.
Hauptserie, *f.* principal series.
Hilfselektrode, *f.* auxiliary electrode.

hochangeregt, *p.a.* highly excited.
hochquantig, *a.* of high quantum number.
Höchstbesetzungszahl, *f.* maximum number of electrons in a shell.
höhensymmetrisch, *a.* (*Cryst.*) symmetrical about the vertical axis.
höherquantig, *a.* of higher quantum number.
Hyperbelbahn, *f.* hyperbolic orbit or path.
Impulssatz, *m.* momentum principle.
inneratomar, *a.* intra-atomic.
intraatomar, *a.* intra-atomic.
Kern, *m.* nucleus.
Kernabstand, *m.* nuclear distance.
Kernaufbau, *m.* nuclear structure; nuclear synthesis.
Kernbewegung, *f.* nuclear motion.
Kernladung, *f.* nuclear charge.
Kernladungszahl, *f.* nuclear charge number.
kernnah, *a.* close to the nucleus.
Kernphysik, *f.* nuclear physics.
Kernschwingung, *f.* nuclear vibration.
Kernspin, *m.* nuclear spin.
Knotenlinie, *f.* nodal line.
Knotenpunkt, *m.* nodal point.
Knotenzahl, *f.* nodal number, number of nodes.
kollidieren, *v.i.* collide.
kontrapolarisieren, *v.t.* counterpolarize.
kräftefrei, *a.* force-free.
Kreiselbewegung, *f.* motion of a top, gyroscopic motion.
Kreiselelektron, *n.* spinning electron.
Kreiselmolekül, *n.* spinning molecule.
kreiseln, *v.i.* spin like a top, rotate with precession.
Kreuzgitter, *n.* cross grating; surface lattice.
Kristallpulver, *n.* crystal powder.
Kugelfunktion, *f.* spherical harmonic.
Kugelschale, *f.* spherical shell.
Kugelsymmetrie, *f.* spherical symmetry.
kugelsymmetrisch, *a.* spherosymmetric.
Kugelwelle, *f.* spherical wave.
Kurvenzacke, *f.* jag (sharp change in direction) in a curve.
Ladungsdichte, *f.* density of charge, charge density.
Ladungswolke, *f.* charge cloud.
Laufterm, *m.* variable term.
Laufzahl, *f.* variable number, running variable.
Leuchtelektron, *n.* emitting electron, optical electron.
leuchtfähig, *a.* capable of luminescence.
Leuchtrohr, *n.* illuminating tube; radiating tube.
Lichtelektron, *n.* photoelectron.
lichthoffrei, *a.* (*Photog.*) free from halo.
Lichtquant, Lichtquantum, *n.* light quantum.
lichtschwach, *a.* (*Optics*) of small intensity.
lichtstark, *a.* (*Optics*) of strong intensity.
lichtundurchlässig, *a.* opaque to light.
Limes, *m.* limit.
Liniengebild(e), *n.* system of lines.
Linienkern, *m.* nucleus (or central part) of a line.
Linienmitte, *f.* middle of a line.
linienreich, *a.* rich in lines.
Linienzahl, *f.* number of lines.
Linienzug, *m.* line, trace (in a graph).
Lochblende, *f.* perforated screen or diaphragm.
Lockerung, *f.* loosening.
Luftmantel, *m.* air mantle, air jacket.
Makromechanik, *f.* macromechanics.
Maschengrösse, *f.* size of mesh.
Massenpunkt, *m.* mass point, center of mass.
Matrizen, *f.pl.* matrixes, matrices.
mehrdimensional, *a.* many-dimensioned, multidimensional.
Mehrlinienspektrum, *n.* many-line spectrum.
Mikromechanik, *f.* micromechanics.
Mischspektrum, *n.* mixed spectrum.
mitbewegt, *a.* (of the atomic nucleus) in relative motion, moving.
Mitbewegung, *f.* relative motion (as of the atomic nucleus).
Mitschwingen, *n.* covibration.
modellmässig, *a.* according to a model, in terms of a model.
Molekülbau, *m.* molecular structure.
Nachbarlinie, *f.* adjacent line, neighboring line.
Nebelkammer, *f.* cloud chamber.
Nebenquantenzahl, *f.* secondary (or subsidiary) quantum number.
Nebenserie, *f.* subsidiary series, secondary series.
Netzschutz, *m.* protecting gauze or grid.
Netzwerk, *n.* network.
Nichtentartung, *f.* nondegeneration.
nichtkohärent, *a.* noncoherent.
Niveau, *n.* level.
Normierung, *f.* normalization, standardization.
Nullinie, *f.* zero line, null line.
Nullniveau, *n.* zero level.
Nullsetzen, *n.* setting equal to zero.
nullt, *a.* zero.—**nullte Spalte,** zero column.
Nullzweig, *m.* zero branch.
Oberschwingung, *f.* overtone, harmonic.
Oktettregel, *f.* octet rule.
Ordnungszahl, *f.* classification number, specif., atomic number.
Ortsfunktion, *f.* position function.
Permanenzsatz, *m.* permanence principle.
Photometrierung, *f.* photometric evaluation or recording.
Platzwechsel, *m.* exchange of places (of electrons).
Plejade, *f.* pleiad.
präzessieren, präzedieren, *v.i.* precess.
Präzession, *f.* precession.
Primärakt, *m.* primary act.
Primärlinie, *f.* primary line.
Primärstrahlung, *f.* primary radiation.
punktsymmetrisch, *a.* of or pertaining to point symmetry, point-symmetrical.
Quant, Quantum, *n.* quantum.
quanteln, *v.t.* quantize.
Quantelung, *f.* quantizing, quantization.
Quanten, *n.pl.* quanta, quantums.
Quantenbahn, *f.* quantum orbit.
Quantenempfindlichkeit, *f.* quantum sensitivity.
quantenhaft, *a.* of or pertaining to quanta, in the form of quanta.
quantenmässig, *a.* pertaining to quanta, in relation to quanta.
quantenmechanisch, *a.* quantum-mechanical.
Quantensprung, *m.* quantum transition, quantum leap or jump.
quantentheoretisch, *a.* of or according to the quantum theory.
Quantentheorie, *f.* quantum theory.
Quantenzahl, *f.* quantum number.
-quantig. -quantum.
Quereffekt, *m.* transverse effect.
Randbedingung, *f.* boundary condition.
Randwert, *m.* boundary value.
raumfest, *a.* fixed in space, stationary.
Raumquantelung, *f.* spatial quantization.
Raumrichtung, *f.* direction in space.
relativistisch, *a.* relativistic.
Restglied, *n.* residual term or member; (*Math.*) remainder in an infinite series.
Richtungsquantelung, *f.* directional quantization.
Röntgenbremsstrahlung, *f.* X-radiation due to checking or impact.
Rosettenbahn, *f.* rosette orbit or path.
Rotverschiebung, *f.* displacement toward the red.
rotverschoben, *p.p.* displaced toward the red.
Rückstosselektron, *n.* recoil electron.
Ruhesystem, *n.* static system.
Ruhmasse, *f.* rest mass, static mass.
Rumpf, *m.* kernel, core (see Atomrumpf).
Rumpfelektron, *n.* inner electron (as distinguished from an optical or valence electron).
Schalenbau, *m.* shell structure.
Schaulinie, *f.* line, curve (in a graph).
Schichtengitter, *n.* layer lattice.
Schrittweite, *f.* interval (as between spectral lines).
Schubvektor, *m.* thrust vector.
Schwebemethode, *f.* suspension method.
Schwebungstheorie, *f.* beat theory.
Schwellenwert, *m.* threshold value, threshold.
Schwingungsgleichung, *f.* vibration equation.
Sechsergruppe, *f.* group of six, 6-group.
Selbstumkehr, *f.* self-reversal (as of a spectral line).
serienfremd, *a.* of another series, of different series.
Seriengrenze, *f.* series limit.
Serienspektrum, *n.* series spectrum.
Singulett, *n.* singlet.
Smekalsprung, *m.* Smekal transition.
Spektralgegend, *f.* spectral region.
Sprung, *m.* transition, leap, jump (of electrons).
sprunghaft, *a.* pertaining to or of the nature of a leap or jump.—*adv.* by leaps or jumps.
Sprungzeit, *f.* time of transition (of an electron).
Störung, *f.* perturbation.
Störungsgleichung, *f.* perturbation equation.
Stosskette, *f.* chain (or succession) of collisions.
Stossquerschnitt, *m.* collision area.
Stosszahl, *f.* number of collisions.
Strahlenoptik, *f.* geometrical optics.
strahlenoptisch, *a.* of or pertaining to geometrical optics.
Strahlungsdruck, *m.* radiation pressure.
Streukörper, *m.* scattering body.
Streulicht, *n.* scattered light.
Streulinie, *f.* scattered line.
Streuspektrum, *n.* scattered spectrum.
Streustrahlung, *f.* scattered radiation.
Streuungswinkel, *m.* angle of scattering.
Streuvermögen, *n.* scattering power.
Streuwelle, *f.* scattered wave.
Streuwinkel, *m.* angle of scattering.
Strichformulierung, *f.* formula writing with lines or dashes (to represent bonds).
Strichgitter, *n.* simple line grating.
Stufengitter, *n.* echelon grating.
subatomar, *a.* subatomic.
Summenregel, *f.* sum rule, rule of sums.
Summensatz, *m.* principle or law of sums.
Symmetrisierung, *f.* symmetrization.
Tauchbahn, *f.* penetrating orbit.
Teilbande, *f.* component band.
Teilniveau, *n.* partial level.
Termschema, *n.* term diagram.

Termwert, *m.* term value.
tiefliegend, *a.* deep-lying.
Tilgung, *f.* extinction.
Trabant, *m.* (in spectra) attendant line, satellite.
Tripel, *n.* triplet.
Tyndallkegel, *m.* Tyndall cone.
überelastisch, *a.* hyperelastic.
Überexposition, *f.* overexposure.
Überlichtgeschwindigkeit, *f.* velocity greater than that of light.
Überschneidung, *f.* overlapping (of lines).
Überstrahlung, *f.* overradiation, overexposure (to radiation).
Umlaufzahl, *f.* rotation number.
Umlaufzeit, *f.* time of rotation, revolution period.
Umwandlungsspannung, *f.* (*Elec.*) transformation potential.
unangeregt, *a.* unexcited, in the normal state.
unerregt, *a.* unexcited.
Ungenauigkeit, *f.* uncertainty, lack of sharpness (of definition).
ungequantelt, *a.* unquantized.
Unschärfe, *f.* lack of sharpness.
Untergrund, *m.* background.
Vektorgerüst, *n.* vector diagram.
Verrückung, *f.* displacement.
Verschiebungssatz, *m.* displacement principle.
Verwaschenheit, *f.* washed-out or faded state, indistinctness.
Verweilzeit, *f.* duration, time of stay.
Vielfach, *n.* multiple.
Viellinienspektrum, *n.* many-line spectrum.
vielliniig, *a.* many-line, multilinear.
Vierervektor, *m.* four-component vector, four vector.
vierkomponentig, *a.* four-component.
vierquantig, *a.* of four quanta, 4-quantum.
Virialsatz, *m.* virial principle.
Vorspektrum, *n.* preliminary spectrum (applied by Goldstein to certain low-temperature spectra).
Vorzugsrichtung, *f.* preferred direction.
Wechselsatz, *m.* exchange principle.
Wellenbild, *n.* wave form.
Wellengleichung, *f.* wave equation.
Wellenmechanik, *f.* wave mechanics.
wellenmechanisch, *a.* wave-mechanical.
Wellenoptik, *f.* wave optics.
wellenoptisch, *a.* of or pertaining to wave optics.
Wellenpaket, *n.* wave packet.
Wellenzahl, *f.* wave number.
Wirkungsquantum, *n.* quantum of action.
Wirkungsquerschnitt, *m.* effective cross section.
Wirkungssphäre, *f.* sphere of action.
Wirkungsvariabel, *n.* action variable.
Zeichenebene, *f.* plane of the drawing, plane of the paper.
Zeitgleichung, *f.* time equation.
Zentralkraftsystem, *n.* central-force system.
Zerfallsleuchten, *n.* decomposition luminescence.
Zerfallsreihe, *f.* disintegration series.
Zusatzfeld, *n.* additional field, supplementary field.
Zusatzglied, *n.* additional term, supplementary term.
Zweierstoss, *m.* collision of two bodies.
zweiquantig, *a.* of two quanta, 2-quantum.
zweireihig, *a.* two-series.
zwischenmolekular, *a.* intermolecular.
Zwischenniveau, *n.* intermediate level.
Zwischenoptik, *f.* intermediate optical device or apparatus.
Zwischenschalten, *n.* insertion (between).

Brief Notices of Recent Publications

Wealth, Virtual Wealth and Debt. FREDERICK SODDY, Professor of Chemistry in the University of Oxford. Second edition. Pp. 320. E. P. Dutton and Company, New York, 1933. Price $2.50. A Nobel prize winner turns his attention to a new field and produces a book that commands the respect of leading economists. In the present edition there have been added a survey of the "new economics" since 1926 and a foreword on the recent American banking crisis.

How to Get a Position in School or College. GEORGE W. COX AND W. H. JONES. Second edition. Pp. 98. Southern Teachers' Agency, Memphis, Tennessee, 1933. Price, $1.00. This little book is very evidently the outgrowth of long experience in observing the interactions of applicants and employers. It is replete with practical, helpful advice.

Basic German for Science Students. M. L. BARKER, Lecturer in German, University of Edinburgh. Pp. 164 +xi. W. Heffer and Sons, Cambridge, England, 1933. Price 6 *s.* Excellent for the student of science who has not previously studied German and who wishes to acquire a "reading knowledge" of the language with a minimum expenditure of time and effort. It is designed for use as a textbook in a formal course, but should also be useful to a student working privately.

Meet the Sciences. WILLIAM MARIAS MALISOFF. Pp. 196. The Williams and Wilkins Company, Baltimore, 1932. Price $2.50. Intended to give the layman a clearer and more tolerant understanding of the organization, contents and aims of the various natural and social sciences, including mathematics and logic. It should also be helpful to the student who contemplates entering the sciences.

Time, Space and Atoms. RICHARD T. COX, Department of Physics, New York University. Pp. 154+x. Figs. 21. The Williams and Wilkins Company, Baltimore, 1933. Price $1.00. An authoritative and delightfully written book for the layman. It is one of the Century of Progress series.

Heat and Its Workings. MORTON MOTT-SMITH. Pp. 240+x. Figs. 50. D. Appleton and Company, New York, 1933. Price $2.00. A very readable presentation in non-technical language by the former head of the department of physics at Colby College and at George Washington University. Suitable for collateral reading in the elementary course.

The Development of Physical Thought. LEONARD B. LOEB, Professor of Physics, University of California and ARTHUR S. ADAMS, Professor of Mechanics, Colorado School of Mines. Pp. 648+xiv. Figs. 120. John Wiley and Sons, New York, 1933. Price $3.75. A textbook of the modern type which was written for use in a three semester-hour general survey course but which can easily be made the basis of a year course. Much traditional material, for example, the usual treatment of lenses, is eliminated to make room for recent developments. There is no sacrifice of emphasis on fundamental concepts, however, and much attention is given to the nature of the scientific method. A unique and valuable feature is a 54-page historical introduction. There are no problems.

American Standards Year Book. Pp. 44. American Standards Association, New York, 1933. Free. Includes an index to the publications of this association.

APPARATUS, DEMONSTRATIONS AND LABORATORY METHODS

A Vapor Pressure Apparatus for Laboratory Use

A MORE satisfactory student apparatus for determining the vapor pressures of a liquid such as ether, at various temperatures, has been designed and constructed. The advantages of this apparatus are better temperature control, practically air-free vapor, convenience of operation, and safety.

The essential features are shown in Fig. 1. The mercury reservoir, *R*, is a cylindrical cavity

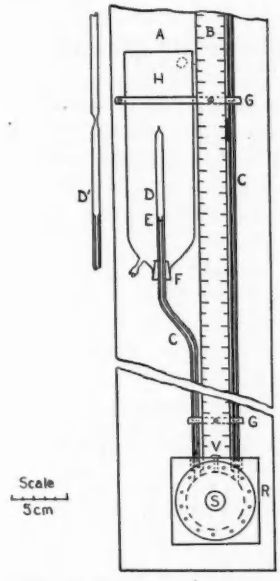

FIG. 1. Diagram of vapor pressure apparatus: *A*, wooden support; *B*, meter stick; *C*, capillary tubing; *D*, *D'*, vapor tube; *E*, index mark; *F*, rubber stopper; *G*, metal clamps; *H*, heating chamber; *R*, mercury reservoir; *S*, thumb screw and plunger; *V*, air vent.

in a block of iron about 3 in. square by 3/4 in. thick, which has been cast and machined to the proper form. One face is hollowed out to form the reservoir, and is fitted with a plate containing a plunger and thumb screw, *S*, for changing the volume of the cavity. A thin leather diaphragm clamped between the plate and block forms the seal.[1] The capillary tubing is sealed into the holes in the block by using either de Khotinsky cement or litharge and glycerine.

The heating chamber is a glass cylinder 2 to 2.5 in. in diameter and about 10 in. long. A portion of the water jacket of a Liebig's condenser serves very nicely. The vapor tube, *D'*, Fig. 1, shows the original form of *D* before filling and sealing off.

After the apparatus has been filled with mercury and all air bubbles have been removed from the reservoir, the tube *D'* and the mercury in the capillary tubing connected to *D'* are thoroughly heated to drive off the air. The tube

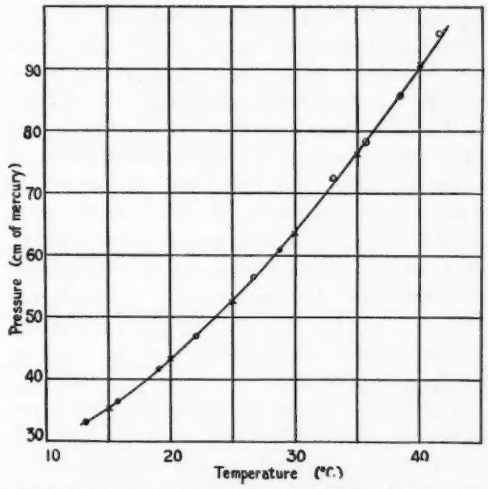

FIG. 2. Vapor pressure curve for ether: circles, experimental values obtained with the apparatus described; crosses, values taken from the *Handbook of Chemistry and Physics*.

[1] I am indebted for this design to Dr. W. R. Wright, of Swarthmore College, who has used it on a Charles' law apparatus.

is then filled with an *excess* of the ether, or other liquid to be tested, and is connected to a small vacuum pump such as an aspirator. When the liquid has evaporated to the desired amount, and with the aspirator still connected, the tube is sealed off at the constriction by means of a small pointed flame.

During an experiment the mercury is kept at some predesignated mark, *E*, by means of the thumb screw, *S*. The heating chamber is filled with water and the pressure and temperature determined in the ordinary manner. The temperature is varied by heating the water with steam or by an electrical device such as a knife-edge heater. For stirring the water, a circular stirrer, loosely fitting the heating chamber and with a small hole in the center, is ideal for student use. The thermometer can be fastened to its handle.

The original position of the index mark with respect to the open mercury arm determines the temperature range. In the case of ether, if the mark is at the 50 cm position on the meter stick, the range is from about 5°C to 50°C. An additional precaution is to fill the reservoir with sufficient mercury so that with the plunger all the way out and the vapor at its lowest temperature the mercury in the open tube stands a few centimeters in height. When finally mounted to a rigid support the apparatus is *almost* "foolproof" except for careless overheating.

A typical set of data taken from a student's laboratory book is shown by the curve in Fig. 2.

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An Improved Franklin's Flask and Simplified Cryophorus

AMONG the lecture table demonstrations on heat, the lowering of the boiling temperature of water by a decrease in the pressure of air above the surface of water is probably one of the most spectacular. The experiment requires a round bottom flask partly filled with water which is made to boil by the application of heat. After the steam has driven off the air the flask is corked and then inverted. Cold water is then poured over the flask, causing condensation of the steam with a consequent reduction in pressure, so that water in the flask continues to boil even though its temperature is below 100°C. The name of Benjamin Franklin is usually associated with this experiment, although the author was unable to find any reference which would indicate that Franklin was the first to suggest or to perform it.

The pouring of cold water on the top of the flask requires a special arrangement for collecting it which can be avoided by a special form of a flask illustrated in Fig. 1. The novel feature of this flask is a spherical cavity, *A*, which is made by heating to the softening temperature the bottom of a one-liter, Pyrex, Florence flask and then drawing it in by suction. The flask is held in a clamp, *B*, with a horizontal rod, *C*, which serves as the axis of rotation when the flask is to be inverted. About 200 ml of water is placed in the flask and a Bunsen flame applied. In order to facilitate uniform boiling, a piece of unglazed porcelain is placed in the water.

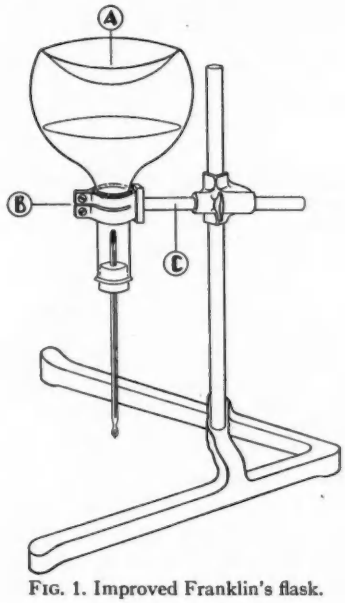

FIG. 1. Improved Franklin's flask.

After one or two minutes of boiling, the Bunsen flame is removed and the flask is closed by means of a rubber stopper through which passes a 100°C thermometer. The flask is now inverted and a piece of ice or solid carbon dioxide is put in its concave bottom. A vigorous boiling begins immediately and continues until the ice is melted. The thermometer meanwhile registers a gradually decreasing temperature which can be carried down to within a few degrees above that of the room if the supply of ice is maintained. These readings may be announced to the class at successive intervals.

In performing the experiment it is well to call the students' attention to the fact that as long as the water is boiling, there is a continuous evolution of water vapor. It is only because of simultaneous condensation that the pressure in the flask is maintained below the vapor pressure of water at that temperature. This condensation takes place on the inside walls of the concave bottom of the flask and is made visible by the formation of water droplets which eventually fall back into the boiling water.

As suggested by Doctor P. E. Klopsteg, this modified form of Franklin's flask can be also used to demonstrate the freezing of water by boiling and evaporation. The required cooling solution may be either liquid air or a mixture of solid carbon dioxide and alcohol. The rapid condensation of water vapor causes such an ebullition that within a few minutes the surface of water begins to solidify, forming a crust of ice a quarter of an inch thick in less than five minutes.

This improved form of Franklin's flask makes it possible to perform the described demonstration with neatness and rapidity. The condensation of steam into water is made visible. Finally, the same flask serves also as a simplified cryophorus.

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Concerning the Program for the Boston Meeting of the A.A.P.T.

AT the next annual meeting of the American Association of Physics Teachers, to be held in Boston in December, a part of the program for the three-day session will be devoted to contributed papers. Members are invited to submit papers which would be of special interest to college teachers of physics. Any one who desires a place on the program should send the title of his paper as soon as possible to the secretary, Professor Wm. S. Webb, Department of Physics, University of Kentucky, Lexington, Kentucky. The rules of the association require that a copy of the paper, or a three-hundred word abstract, be in the hands of the secretary not later than November 15.

The New Committee on the Teaching of Premedical Physics

THE personnel of the new A.A.P.T. committee on the teaching of physics for premedical students has been announced by President Palmer as follows: D. L. Webster, Stanford University, *Chairman*, D. W. Bronk, University of Pennsylvania Hospital, W. E. Chamberlain, Temple University Medical School, D. W. Cornelius, University of Chattanooga, L. G. Hoxton, University of Virginia, C. T. Knipp, University of Illinois, N. C. Little, Bowdoin College, K. K. Smith, Northwestern University, W. R. Wright, Swarthmore College.

President Ray Lyman Wilbur, Stanford University, and Doctor Harold B. Williams, College of Physicians and Surgeons, New York, will serve as advisory members.

DISCUSSION AND CORRESPONDENCE

Contributions to these pages are invited. They should be concise and may deal with articles and abstracts published in previous issues, or with other subjects of professional interest. Among the topics that are appropriate for discussion are: common misconceptions and errors that are fostered by current textbooks, new ideas on classroom technique, unexploited everyday phenomena that illustrate physical principles, historical material, terminology and notation, and requests for information.

Too Slow to be Isothermal?

IN the February number, page 18, Professor E. U. Condon shows beautifully that usually the frequency of sound is too *low* for isothermal conditions and hence that the vibrations are adiabatic, which is well known. This is true if the velocity is kept constant. But if the wave-length is kept constant by varying the medium as the frequency is varied, then the frequency is too *high* for heat conduction to be effective. This usual idea exists probably because the assumption of a constant distance for the heat to travel is a great mental convenience. Of course, Professor Condon's point of view is more in keeping with the usual practical problem, but either point of view is philosophically correct.

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Cook-Book Laboratory Work

A FRIEND of mine told me that the laboratory work in chemistry in the high schools of Prussia was conducted somewhat in this fashion. The instructor would line up all the students and march them in military order into the laboratory. In the laboratory, commands were given: "March to your desks." "Take bottle number two in your right hand." "Take test tube number four in your left hand." "Pour five milliliters of bottle number two in test tube." "Replace bottle number two." "Take number three." "Pour six milliliters in the same test tube." "March to your desks." "Write that you have seen the reaction of silver nitrate and hydrochloric acid."

This method of conducting laboratory work seemed to me very amusing, but somehow the procedure sounded to me very familiar. When I opened a laboratory manual the reason for the familiarity of the commands became apparent. Let me quote from this laboratory manual at random: (1) Start gas meter. . . . (2) Weigh tea kettle. . . . (3) Fill it about. . . . (4) Take temperature. . . . (5) Note reading. . . . (6) Note the time. . . . There seems to be very little difference between the commands given by the old Prussian instructor and the laboratory instructions of this manual. Nor is this method of procedure confined to the book from which I am quoting. Practically all the laboratory books with which I am familiar have directions made by the same pattern.

Of course there is nothing wrong in giving laboratory instructions in this fashion if it helps to attain the aim of our laboratory work; if what we wish students to accomplish can best be obtained by this method of instruction. The question, therefore, is, what is it that we expect a student to get out of laboratory work? If the object is to teach the student to follow certain directions, then these detailed instructions are not only useful, but essential. However, no one would seriously maintain that there is great value in teaching the student to follow instructions of disciplinary character.

The accuracy of results obtained by the student is very often considered to be of prime importance. Here again detailed instructions are useful and essential, as the student would get results more quickly and more accurately with their aid. There is something to be said in favor of having the experiment performed with as high a degree of precision as the apparatus will permit. There is a great deal of satisfaction for the student and for the instructor in getting results which agree with those produced by famous and careful experimenters; and if

this were the only aim, then the more detailed the instructions are, the more particularly each step is outlined, the more we eliminate the judgment of the student, the better, in all likelihood, will the data be.

However, it seems to me that obtaining accurate results by following a book is of very little value. The most precise measurements that have been made can now be repeated with very little difficulty by a student of average intelligence. There are devices on the market which enable even a layman to perform some of the most difficult classical experiments if the manufacturer's instructions are followed in detail. I doubt whether a student is likely to get very much out of such a process.

I was a guest at one time in a house of a professor of physics who served a very excellent cake that he himself had made. I complimented him on his culinary skill, but he said that he was not guilty of any skill; all he did was to follow the cookbook. He knows no more about cooking now than he did before he started following the recipes. I fear that our students are very much in the same position. They gain very little from this sort of procedure. It is true that they get "results," but those results have been obtained before and therefore they will not contribute anything to our knowledge of physics, and the performers get very little out of such a procedure. Obtaining results is to my mind one of the least important objectives of laboratory instruction.

Well, what is it that we wish to get out of laboratory work? In the first place, the most obvious aim of laboratory work in a given science is to understand the science better. The student should be given a clear understanding not only of the laws which enable us to predict the results he wishes to verify, but also the principles underlying the behavior of the apparatus with which he is working. He should be able to observe the laws in action, so to speak, while he is doing the experiment. Therefore, a complete description of the theory of any given experiment must be presented to the student. It is extremely curious that this part of laboratory work is usually left to the student; that is, the student is advised to go to some textbooks and get the theory of the given experiment by himself. It is assumed that the theory of the experiment is very easy and not very important, and that the student can get it without the aid of anyone; but what to do with apparatus is another matter—it is both difficult and important. The student cannot get that himself and it must be explained to him in very great detail. My experience indicates that the reverse is the case. It is very seldom that a student has been able to get a clear idea of the theory underlying the given experiment. Usually he merely copies from the textbook to which he is referred without understanding in the least what it is all about. By the theory of a given experiment I do not mean the derivation of the formula which the student is trying to prove. This is of very little value. The proof of a certain relationship is of no use unless the reasoning behind every portion, every step, in the derivation of this relation is clear to the student and in some way or other is related to the performance of the experiment.

It has been my experience that, with a proper understanding of the theory of a given laboratory exercise, a student of average abilities will perform the experiment and use the apparatus fairly intelligently. The emphasis, therefore, should be not on the mechanical procedure, but on the theory, on the complete understanding of what he is trying to do and the understanding of the apparatus at his disposal. One gain that the student is expected to derive from laboratory work is, therefore, a clear conception of the laws underlying a given experiment and a clear understanding of the behavior of the apparatus.

Another aim of laboratory work is to tax the student's ingenuity and capacity for reasoning. A recent issue of *Science* contains a description of some experiments of anthropologists with apes, in which the ape is given a stick and a delicacy out of his reach, the idea evidently being to teach the ape the use of the stick if he is to gratify his desires and obtain the delicacy. We trust our students less than that anthropologist trusts his apes. We give the student the stick and the delicacy and we tell him exactly what to do with the stick in order to get the desired results. We do not trust him to use his brains, and therefore he does not use them. I think it would be very advantageous to sacrifice a part of the precision in the results for a more intelligent and independent performance of the experiment.

Cookbook instructions certainly do not stimulate the student's capacity for reasoning or his ingenuity. If anything, these are stifled under such a procedure. The instructions for carrying out a given experiment should be conspicuous by their absence or they should be implied in the discussion of the theory of the experiment.

There is a tendency in laboratory work as well as in recitation work to cover too much ground in a given time. There is a feeling that there would be a deplorable gap in the student's mind if a given portion is omitted or some experiment left undone. It is believed that some mysterious benefit would result to the student if he does obtain a straight line when he plots the results of a given experiment, without which a lack of appreciation of the science might result. We forget that the actual information gained by the student will evaporate very quickly after the examinations. This attitude of covering ground is responsible for the tendency still common in many institutions to do a great many exercises in a limited time allotted to laboratory work; in some cases less than two hours is allowed for each exercise. The benefit from such a procedure is, to say the least, very doubtful. It is time to realize that the results are of much lesser importance than the process by means of which these results are obtained.

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ABSTRACTS

Abstractors for This Number: R. J. Havighurst, F. E. Knowles, Duane Roller, William Schriever, G. A. Van Lear, Jr.

Apparatus, Demonstrations and Laboratory Practice

104. A laboratory cooling unit. D. H. Cook; *Ind. and Eng. Chem.*, Anal. Ed. **5**, 147–148, Mar., 1933. Tells how a small Frigidaire unit may be modified so as to serve as an adequate supply of cold water for laboratories located in a hot climate. The unit has also been found of service in photographic work and is less expensive than the cooling machines made expressly for this purpose. D. R.

105. An automatic pressure-regulating unit for vacuum distillation. E. H. Huntress and E. B. Hershberg; *Ind. and Eng. Chem.*, Anal. Ed. **5**, 144–146, Mar., 1933. Describes a simple portable regulator capable of maintaining to ±0.15 mm any pressure within the range of 2 to 30 mm. A Cenco Hyvac pump is operated intermittently by the action of a thermionic relay system which is connected to a manostat. The manostat is essentially a U-tube mercury manometer, equipped with tungsten electrodes which are sealed in at the U-bend and at the top of the arm which connects with the system, respectively. A given pressure is obtained by fastening the manostat in a given inclined position. A list of references to the literature describing various types of pressure-regulating devices is given. In using solid carbon dioxide on the vapor trap, the authors recommend the use of a mixture of equal weights of chloroform and carbon tetrachloride for the low-freezing heat transfer liquid; all fire hazard is thus avoided and the carbon dioxide floats on the surface of the liquid. D. R.

106. Improved laboratory screw clamp. W. A. Sperry; *Ind. and Eng. Chem.*, Anal. Ed. **5**, 188, May 15, 1933. As an ordinary (Hofmann) screw-compressor tubing clamp is equipped with a screw head that is too small, the thumb and fingers of the operator often suffer injury in manipulating it and pliers must often be used. To remedy this, braze a knurled brass cup of the appropriate depth and diameter to the original screw head, the brazing being accomplished through a small hole in the center of the cup. This also facilitates fine adjustment when the clamp is used for regulating the flow of a gas or liquid through rubber tubing. A second type of device for the same purpose is also described in the article. D. R.

107. Air pressure for blast lamps. G. W. Thiessen and J. E. Wertz; *Ind. and Eng. Chem.*, Anal. Ed. **5**, 201, May 15, 1933. A second-hand vacuum sweeper from which the dust plate and unnecessary accessories have been removed makes an efficient substitute for an air-pressure pump and tank for glass blowing. By using a large rubber stopper, in which a Y-tube is inserted, in the manifold where the dust bag is ordinarily clamped, three blast lamps can be supported easily. D. R.

108. Surface tension and its measurement. Allan Fergurson; *J. Sci. Inst.* **10**, 34–37, Feb., 1933. A lecture, with experimental demonstrations, on the more important of the fundamental properties of surface tension. G. A. V.

109. Design of an apparatus for cathode sputtering. James A. Darbyshire; *J. Sci. Inst.* **10**, 83–85, Mar., 1933. Gives details of the construction and operation of an apparatus for sputtering thin metallic films on glass or collodion. References to previous papers on this subject are given. G. A. V.

110. Vee pulleys. G. R. Myers; *J. Sci. Inst.* **10**, 90, Mar., 1933. Describes a simple method for making a Vee pulley from a brass disk. Disks of various sizes and thicknesses can be bought by the pound. G. A. V.

111. A laboratory modification of the Pulfrich refractometer. V. N. Thatte; *J. Sci. Inst.* **10**, 120–121, Apr., 1933. One of the methods used in undergraduate courses for determining the refractive index of a liquid is

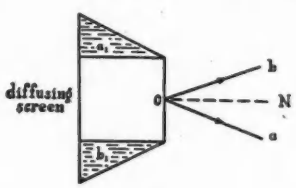

Fig. 1.

based on the principle of the Pulfrich refractometer. The present article describes a modification of this method which is more rapid, simpler to observe and equally accurate, and which can be used with a simple telescope mounted on a graduated circle. Two triangular glass chambers on either side of a glass block are illuminated by light from a sodium flame with a single diffusing screen (Fig. 1). "The telescope is first set along direction a on the line of separation between the dark and bright halves of the field of view due to the beam from chamber a_1 and then along the corresponding direction b in the beam from chamber b_1. Half the angle between these two positions of the telescope gives the necessary angle for calculating the refractive index." D. R.

112. The Nevson Tangraph rule. ANON; *J. Sci. Inst.* **10**, 4, 119–120, Apr., 1933. The rule consists of a strip of thin celluloid about 10 inches long, down the center of which is engraved a straight line having a number of short perpendicular transversals, equidistant and of the same length. A number of small holes are drilled through the rule at different points along the central line. To draw a tangent at any point on a curve, one of the points on the rule where a transversal cuts the central line is placed over the point in question and the rule is adjusted until the intercepts made by the curve on two transversals, equidistant from the point, are equal. Dots are then marked on the paper by the point of a pencil inserted through two of the holes in the rule, which is then removed, and a straight line, the tangent, drawn through the two dots. The rule may also be used for drawing linear graphs, by adjusting it so that the points are evenly distributed about the central line. It is flexible and may be used for drawing curves. There are millimeter and inch scales along the edges. The rule is made by Messrs. G. Cussons, Ltd., Manchester, Eng. D. R.

113. The Angstrom pyrheliometer in the laboratory. G. A. SHOOK; *Pop. Astron.* **41**, 254–259, May, 1933. Gives detailed instructions for constructing an Angstrom pyrheliometer that is suitable for measuring the solar constant in the student laboratory. The usual difficulties in construction, which lie in the use of short thin platinum strips and a delicate thermocouple, are surmounted in the present design by utilizing a comparatively long Nichrome or Chromal ribbon for the strips; the thermocouple wires can then be made of a size that can be handled readily by anyone who has some skill in soldering. The instrument is somewhat more complicated mechanically than a simple form of pyrheliometer like the Pouillet instrument but it has the advantage that no radiation correction need be made for approximate results. D. R.

114. Jig for bending copper tubing. ANON; *Pop. Mech.* **59**, 800, May, 1933. Instructions are given for making and operating a device for bending thin-walled copper tubing. Spiral coils, U-bends or angles may be formed. F. E. K.

115. Test tells when prints are free of hypo. ANON; *Pop. Mech.* **59**, 944, June, 1933. Directions are given for making and using a solution of permanganate of potash, caustic soda and water for determining whether enough of the hypo has been removed from a photographic print to prevent the print from turning yellow. F. E. K.

116. Tricks of sharpening knives and other straight-edged tools. W. CLYDE LAMMEY; *Pop. Mech.* **59**, 951–953, June, 1933. Gives instructions, with illustrations, for sharpening tools such as are used about a laboratory. Information is given as to suitable bevels for the cutting edges, how to keep stones in condition, and how to hold the tool while it is being sharpened. F. E. K.

117. Black bulbs' invisible light aids photography in dark. ANON; *Pop. Mech.* **60**, 62, July, 1933. Attention is called to "two" black lamps put out by the Westinghouse Lamp Company. Ninety-nine percent of the visible light is absorbed and about eighty-five percent of the ultraviolet is transmitted. F. E. K.

118. How to make thermocouples. ANON; *Pop. Mech.* **60**, 154, July, 1933. Students should be interested in this article which gives simple instructions for making thermocouples and tells how, with the aid of a millivoltmeter, one may measure temperatures up to 2000°F. F. E. K.

119. Removing welding-torch tips. HALLIE P. DAVIDSON; *Pop. Mech.* **60**, 160, July, 1933. Instructions are given for removing tips in welding-torches that stick or are broken. A welding-torch head is expensive and it is practical to know how to make necessary repairs. F. E. K.

120. Experiments with ultra-short electric waves. N. L. YATES-FISH; *Proc. Phys. Soc.* **45**, 482–484, May, 1933. Details are given for the construction of a transmitter and receiver for demonstration purposes. Two screens, formed by stretching copper wires parallel to one another and 2 cm apart across wooden frames 122 cm square, are also used in the experiments. One of these screens can be used to show that the waves are plane-polarized, and to cause a rotation of the plane of polarization. By using both screens, the reflection of waves can be demonstrated. The action of the Heaviside layer in producing fading of signals can be effectively illustrated by placing a large metal sheet parallel to the plane containing the two antennas and moving it to and fro to simulate changes in the effective height of the layer. D. R.

121. Capillary adsorption due to surface tension. D. OWEN; *Proc. Phys. Soc.* **44**, 521, July, 1932. Two strips of filter paper are suspended vertically with their ends dipping into two beakers, one of which contains red ink and the other red ink to which sodium chloride has been added. The water rises farther than the dye but the difference between the colored and uncolored levels is increased in the presence of the salt. Red ink has a surface tension slightly lower than that of water, whereas an aqueous solution of salt has a surface tension exceeding that of water. D. R.

122. An old experiment in new dress. NOEL C. LITTLE; *Sch. Sci. and Math.* **33**, 373–377, Apr., 1933. The acceleration of gravity is determined by a method similar to that employed by Galileo for studying motion with constant acceleration. The apparatus consists of a 1-in. steel ball bearing and two grooved inclined planes placed end to end, in the shape of a V, with the apex of the V resting on a steel plate. Each inclined plane is formed by clamping together two 0.5-in. steel rods of about 1 yd. length. To adjust the two pairs of rods to equal angles of inclination with the steel plate and to measure this angle, a ball bearing is placed between each incline and the plate and the inclines are adjusted until the balls are equally distant from the apex of the V. The ball is started at the top of one incline, the time is noted as it clicks on passing over the apex of the V, successive distances to which the ball ascends on both sides are observed and, after a number of such excursions, the time of passing through the apex is again noted. A simple, inexpensive timing device can be made from a 2-watt Telechron motor having 1 r.p.m. The motor is placed in a wooden frame and an aluminum disk, about 1 ft. in diameter and graduated in degrees, is mounted on the axle so as to rotate behind a fixed pointer. D. R.

123. The ripple tank and the Doppler effect. HIRAM W. EDWARDS; *Sch. Sci. and Math.* **33**, 537–539, May, 1933. Describes a compact and easily constructed apparatus, consisting of an arc lamp, mirrors, ripple tank and auxiliaries, all mounted ready for use on a single table. The ripples are projected on a vertical screen. Disturbing reflections from the sides of the tank are eliminated by introducing a sloping "beach" which is made of soft wax. The vibrator, which is used to provide plane waves, is mounted on a movable frame, thus making it possible to illustrate the Doppler effect. D. R.

124. A simple resonance spring. THOMAS D. PHILLIPS; *Sch. Sci. and Math.* **33**, 551, May, 1933. Describes a device for demonstrating the transfer of energy from one mode of vibration to another when the two are in resonance. A spiral spring is hung from a rigid support and a hook is bent in the lower end of the spring in such a way that the hook is at one side rather than on the axis of the spring. Weights are hung from this hook until the period of pendular vibration, to-and-fro, is related to the period of vertical vibration of the spring in a ratio of two to one. The only limitation on the choice of spring is that the relation of length and stiffness be such that the specified ratio of periods can be obtained. Besides its ease of construction, the device has the further advantage that the explanation of its action is simple. D. R.

125. Repairing broken mercury columns in thermometers. J. R. ENDSLEY; *Sch. Sci. and Math.* **33**, 547, May, 1933. The method consists essentially in rigidly suspending the thermometer in enough glycerine or other high boiling-point liquid to cover the mercury bulb and then heating the glycerine slowly until the mercury below the last gap in the column rises into the cavity at the top of the tube; the burner is then removed and the thermometer is tapped gently near the top. If mercury sticks in the cavity at the top of the tube, it can be dislodged by inverting the thermometer, heating it until most of the mercury has been driven out of the cavity, and then suddenly righting it. D. R.

126. An elementary study of diffraction patterns. JOHN B. DUTCHER; *Sch. Sci. and Math.* **33**, 604–610, June, 1933. Describes the construction of a simple, inexpensive "diffraction camera" which has been used with success at Indiana University. D. R.

127. Experiments with liquid air. HAROLD A. IDDLES, JAMES A. FUNKHOUSER AND ALFRED H. TAYLOR; *Sch. Sci. and Math.* **33**, 668–671, June, 1933. (1) Pour 50 ml of liquid air upon water contained in a beaker; the air at first floats but soon bubbles begin to sink as the nitrogen boils away leaving the heavier oxygen. Toward the end, test for oxygen with a glowing splinter. (2) Pump liquid air over cranberries until they rattle against the glass like marbles when shaken. (3) Mix equal parts of alcohol and liquid air by means of a stirring rod. (4) Prepare a mold by drawing down the end of a test tube to a conical form and cutting off the tip of the cone. Thread a string through the opening to serve as a wick, pour some kerosene in the tube and immerse the latter in liquid air. When the kerosene is just frozen, remove it by dipping the tube for an instant in water. Place this candle in a candlestick and light it. (5) Demonstrate the tendency of red lead, sulphur, copper sulphate, etc. to change color when the test tubes containing them are cooled in liquid air. (6) Place liquid air in a cannon made from brass pipe; when the pipe has become thoroughly cool, drive a cork into the mouth of the pipe. (7) Bend over the closed end of a tube to make a trap in which cocoanut charcoal is placed. Support the tube vertically with the open end in a mercury well, and then immerse the trap in liquid air. Compare with a manometer which indicates atmospheric pressure. (8) Liquify natural or Pyrofax gas by passing it to the bottom of a small distilling flask the bulb of which is immersed in liquid air. Then turn off the gas, allow the bulb to warm up and light the gas which issues from the side tube. (9) A helical spring made of wire solder will support a relatively large weight after it has been cooled in liquid air. A lead bell similarly cooled will emit a metallic sound. (10) Connect an automobile headlight bulb to a battery through a coil of fine copper wire of about 15 ohms resistance and then dip the coil in liquid air. (11) Suspend a test tube containing liquid oxygen so that it is free to swing as a pendulum near a powerful electromagnet which is operated intermittently; later on, drop a tack into the tube. Details regarding these experiments, and a number of others, are given in the article. D. R.

128. Experimental dynamics—some criticisms and suggestions. W. O. CLARKE; *Sch. Sci. Rev.* No. 54, 176–186, Dec., 1932. After pointing out the shortcomings of the various methods in common use for illustrating and verifying by experiment the laws of force and acceleration,

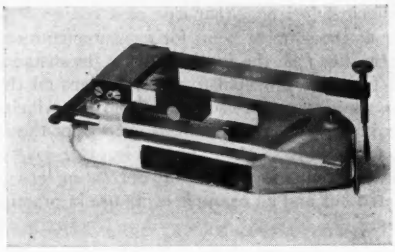

FIG. 1.

the author describes a modified form of the Fletcher trolley in which the vibrating spring is mounted on the trolley instead of on a fixed bridge (Fig. 1), and the trace is taken on paper fixed to the plane on which the trolley runs. A spring-controlled dynamometer fitted with an ink-brush is fixed to the trolley and marks a curve, alongside the distance-time trace, of which the ordinates are proportional to draw-bar pull. Typical experiments involving variable acceleration are described. By a method which depends on the principle of the wedge-gauge, accelerations may be computed rapidly from the distance-time curve. D. R.

129. Home-brewing the rainbow—and understanding it. GAYLORD JOHNSON; *Sci. Am.*, 156–158, Mar., 1933. A simple experiment is described, which demonstrates to the observer just how a rainbow is formed. Two 2-in. crystal "gazing balls," such as one often sees in an optician's window, are the only special parts required (one would be sufficient). Each ball is mounted in a hollow horizontal cylinder of black paper half way through which is cut a narrow vertical slit—the center of the sphere being directly in the plane of the slit. The two cylinders are mounted on a suitable stand which must have an arrangement for allowing one to be moved vertically relative to the other, the two slits being in the same vertical plane. This stand is placed in the direct sunlight, the plane of the slits passing through the observer and the sun, and the observer standing between the sun and the spheres. With the sun 40 degrees or less above the horizon, the observer raises and lowers his head so as to see the flash of light which is reflected at the inside surface of each sphere. The light from each sphere will be spread out in colors, the red being the lowest for each sphere. In the case of the rainbow in nature there are millions of such spheres (obviously much smaller), and there are always some in just the right positions to reflect the color into the eye, no matter at what level the eye is. Thus at any one moment, for a given position of the sun and the eye, there exists a conical sheet of drops in the rain (the apex of the cone at the eye), which drops are momentarily in just the right positions to reflect the red rays into the eye. Inside of this conical sheet is another conical sheet of drops (with the apex at the eye) which drops are in just the right positions to reflect the violet rays into the eye. Between these two sheets are other sheets of drops each of which reflects a particular color into the eye. Instructive diagrams and photographs illustrate this interesting article. W. S.

130. The electric radiant heater as an aid in electrostatic experiments. W. P. WESTPHAL; *Zeits. f. Math. u. Naturw. Unterricht aller Schulgattungen.* **64**, 178–179, No. 4, 1933. Electrostatic machines and other instruments may be used even in very damp weather after they have been exposed for a few minutes to the radiation of an electric radiant heater. R. J. H.

131. The purification of mercury. M. ZUPPKE; *Zeits. f. Physik u. Chemie Unterricht.* **45**, 161–162, July–Aug., 1932. Washing mercury with nitric acid or potassium bichromate solution results in loss of mercury. The author states that if a vigorous stream of air is sucked through dirty mercury by means of a water-pump for several hours most of the metallic impurities will be oxidized and can be removed by filtration. R. J. H.

132. A simple experiment to show the density anomaly of water. K. WILDE; *Zeits. f. Physik u. Chemie Unterricht.* **46**, 118–119, May–June, 1933. With a beaker of about 10 cm diameter, cover the bottom with a pad of rubber and press a lamp chimney or straight-sided glass cylinder of about 5 cm diameter against the rubber mat. Pour into the space between the cylinder and the beaker wall some water at 4°C, and fill the inside of the cylinder to an equal height with water at 0°C which has been slightly colored with potassium permanganate. Wait a few seconds until the water is still, and then remove the cylinder without horizontal motion. The colored zero-degree water will float upon the colorless four-degree water. In the same way it can be shown that warm water floats upon cool water above 4°C. R. J. H.

GENERAL PHYSICS AND RELATED FIELDS

133. Cosmic rays—what physicists have learned about them. KARL K. DARROW; *Elect. Eng.* **52**, 221–228, Apr., 1933. An excellent review. Well illustrated. G. A. V.

134. Freezing-point lowering. THOMAS B. GREENSLADE; *J. Chem. Ed.* **10**, 353, June, 1933. Few textbooks in first-year college chemistry attempt an explanation of the lowering of the freezing point of a pure solvent by the addition of a solute and those that do, employ a vapor pressure-temperature diagram that is not understood by the students. The author suggests an explanation which is based on the kinetic molecular theory. "Let us consider a

unit surface between water and ice in equilibrium at 0°C. In any given unit of time there are as many molecules leaving the ice and entering the liquid state as there are molecules leaving the water and forming solid. Suppose now that we add a solute such as sodium chloride to the mixture. The salt dissolves in the water, and we have a solution in contact with ice. Since the number of water molecules per unit volume in the liquid has been diminished by this addition of solute molecules, the rate of ice formation is decreased. Now there are more molecules changing from the solid to the liquid state than are returning to the solid, heat is absorbed, and the temperature falls. This lowering of the temperature continues until it effects an equalization of the rates of ice and water formation. At the temperature at which this occurs a new equilibrium is established between ice and solution, and they can exist in contact with each other. This is, by definition, the freezing point of the solution." D. R.

135. Magnification scales for a convex lens. E. M. EDEN; *J. Sci. Inst.* **10**, 89, Mar., 1933. Fig. 1 shows the position of object and image for a thin convex lens for any magnification. "The scale to the left of the lens shows the magnification of the 'object' compared with the 'image' or the ratio (*size of object*)/(*size of image*) for any position of the object.

FIG. 1.

The scale to the right shows the magnification of the image compared with the object or the ratio (*size of image*)/(*size of object*) for any position of the image. The two magnification scales are identical but are on opposite sides of the lens; the distance of the zeros of the scales from the lens is the focal length f and the unit of the scale is also f. If, for example, the object is 4 times the size of the image, the object will be at A, and as the image is ¼ size of the object the image will be at A': the distance of the object from the lens is $5f$ and the distance of the image from the lens $1\frac{1}{4}f$. The diagram solves all the problems of the positions of the image and the object practically by inspection. *Example.* The distance from object to image is to be 36 in. Find the focal length of the lens to be used for a magnification of 3 times. As the object magnification is to be ⅓, the object will be at F and the image magnification being 3 the image will be at F'—by inspection the distance from object to image is seen to be $5\frac{1}{3}f$, and this distance is to be 36 in.; $f=36/5\frac{1}{3}=6.75$ in. The diagram is so simple that it can be memorized and will be found more convenient and safer to use than the textbook formulas."
D. R.

136. Magnification scales for a convex lens. JULIUS RHEINBERG; *J. Sci. Inst.* **10**, 158, May, 1933. The author points out that Mr. Eden's diagram (Fig. 1, Abstract 135) demonstrates the great value of treating the position of the principal foci on either side of a convex lens or objective as the starting point for measurements or for lens formulas. Let f be the focal length, o the distance of the object from the principal focus of the lens on the object side, m the distance of the image from the principal focus on the image side, and r the ratio of size of the image to that of the object; then, from Fig. 1, $r=m/f=f/o$, or $f^2=om$. The simplicity of this way of treating lens problems is pointed out and an example of its use in practical work is given. D. R.

137. Recent advances in physics. W. F. G. SWANN; *Mech. Eng.* **55**, 75–79, Feb., 1933. Modern atomic theory. Nonmathematical. G. A. V.

138. Recent researches on the transmutation of the elements. E. RUTHERFORD; *Nature* **131**, 388–389, Mar. 18, 1933. In this Friday evening discourse delivered at the Royal Institution, the author points out that it is now well established that the change of one atom into another can be effected only by the addition or subtraction of one of the constituent particles of the atomic nucleus. The author describes briefly the effects of bombardment of matter by α-particles and protons. Excellent for student reference.
D. R.

139. The physical nature of the nerve impulse. A. V. HILL; *Nature* **131**, 501–508, Apr. 8, 1933. A Friday evening discourse delivered at the Royal Institution which contains material of value for premedical physics. D. R.

140. Life on other worlds. FREDERICK C. LEONARD; *Pop. Astron.* **41**, 260–263, May, 1933. A popular discussion of "the question most frequently put to the astronomer by the person who knows little or nothing about astronomy."
D. R.

141. Forecasting weather is easy with a barometer. ANON; *Pop. Mech.* **59**, 774, May, 1933. Gives directions, with illustrative examples, for amateur weather forecasting by means of an aneroid barometer. F. E. K.

142. Some fundamental principles of electrical communication. J. W. HORTON; *Sch. Sci. and Math.* **33**, 441–447, Apr., 1933. The author, who is connected with the General Radio Company, discusses some of the implications of the principle that "the rate at which information is transmitted over a wave communication system is directly proportional to the extent of the frequency range occupied by the sinusoidal components of the signal wave." It is doubtful whether our present telephone network can be utilized for both television and telephony, since it appears that its information-carrying capacity would have to be increased about 20 times above that now available. Short-wave radio at present offers the most promising medium for television. D. R.

143. Why it is unsafe to swim near a pier during a thunderstorm. MORRIS WISTAR WOOD; *Sch. Sci. and*

Math. **33**, 552–554, May, 1933. The author describes some novel experiences gained while swimming near a pier during a thunderstorm and discusses their physical implications. D. R.

144. On facts and fancies in cosmogony. HARLOW SHAPLEY; *Sigma Xi Quar.* **21**, 1–2, Mar., 1933. A brief but illuminating summary of present ideas of the origin of sidereal bodies. The origin of the moon out of the earth has been heretofore the only well-considered hypothesis of lunar genesis but Jeffries has recently proved its impossibility; a tremendous amount of observational data on the earth and moon has been accumulated without yet providing a convincing clue to the mystery of the origin of these bodies. Similarly, there exist abundant data on the planets, but the nebular hypothesis yielded to the planetesimal hypothesis and other variants of a tidal evolutionary theory without giving general satisfaction; we now have veered back toward an earlier collision origin of the planets from the surface of the sun. The author suggests that future researches "be directed to (a) a consideration of the general time scale of the universe; (b) a study of the place of asteroids and comets in the solar system; (c) further exploration of the trans-Neptunian region . . .; (d) investigations of the interior structure of the earth; and (e) the increased knowledge of secular changes in the orbital elements of the planets throughout great intervals of time." He proposes consideration of the possibility "that moon, planets and sun are all of the same age and that they have arisen in a secondary swirl or eddy of the parental spiral nebula out of which the local galaxy may be supposed to have generated." With regard to the evolution of the stars and of galaxies of stars, we are now practically without any theory. Perhaps one of the most important observational contributions in recent years has been the demonstration of the existence of cosmic meteors. The author also points out, among other things, the value of discriminating between observations plus reasonable interpretations thereof, and speculations that must be based on much more than is measured. D. R.

INTERMEDIATE AND ADVANCED PHYSICS

145. The Fermi-Dirac statistical theory of gas degeneration, with some application to electronic phenomena in metals. VLADIMIR KARAPETOFF; *Mech. Eng.* **55**, 237–242, Apr., 1933; 290–294, May, 1933. This series of articles offers to the reader who is unacquainted with statistical methods the simplest possible introduction to the Fermi-Dirac statistics and the electron theory of metals. D. R.

146. Superconductivity. J. DE BOER; *Sci. Prog.* **27**, 613–633, 1933. A summary of the experimental results on the superconductivity of elements and alloys and the relation between superconductivity and other physical properties. A comprehensive list of references is included. D. R.

HISTORY AND BIOGRAPHY

147. The battle of the alchemists. KARL T. COMPTON; *Elec. Eng.* **52**, 75–80, Feb., 1933. A review of Man's accomplishments in the transmutation of the elements, from the time of ancient mythology "down to the time of our present-day alchemists, the modern physicists." "The goal of today's battle is not precious metals, but energy." D. R.

148. The development of the fundamental concepts of infinitesimal analysis. F. L. WREN AND J. A. GARRETT; *Am. Math. Mo.* **40**, 269–281, May, 1933. Historical notes which cover the period ending with the first quarter of the nineteenth century. W. S.

PHYSICS TEACHING AND SCIENCE EDUCATION

149. An attempt to study the effect of scientific training upon prejudice and illogicality of thought. JAMES HUNTLEY SINCLAIR AND RUTH SHERMAN TOLMAN; *J. Ed. Psych.* **24**, 362–370, May, 1933. A group of about 100 freshmen and seniors from California Institute of Technology and a similar group of freshmen and senior men from Occidental College were given the Goodwin-Watson test on prejudice and ability to draw inferences. The prejudice test is designed to measure the amount of prejudice held concerning economic, social, and religious problems, and the inference test is supposed to measure the ability to draw conclusions from stated facts. The C.I.T. students were superior in both tests, but seniors were relatively no more superior to Occidental seniors than freshmen were to Occidental

freshmen. The C.I.T. students were more superior on the inference test than on the prejudice test. From these results the authors conclude tentatively that the study of science in college does not improve the ability to draw inferences nor does it eliminate prejudice more effectively than the study of liberal arts in general, but students who select a scientific vocation are superior in these respects at the beginning of their college experience. R. J. H.

150. The value of secondary school subjects in the preparation for medicine. GRAYSON N. KEFAUVER AND GORDON N. MACKENZIE; *Calif. Quar. Sec. Ed.* **8**, 159–171, Jan., 1933. A summary of the replies of 42 deans of medical schools shows that chemistry, physics, biology and zoology are considered by them to be the most important. D. R.

151. The projection of quiz questions. FREDERIC B. DUTTON; *J. Chem. Ed.* **10**, 376, June, 1933. The author finds that true-false and multiple-choice questions typed on Cellophane (Abstract 45, *Amer. Phys. Teacher*, 1933) and projected on a screen, reduce to a minimum the work and cost of administering and grading quizzes, and make it possible to give numerous short quizzes. The use of a short-focus lantern and daylight screen is recommended. A new type of carrier for the roll film is described. D. R.

152. The tetrahedron test of power to visualize. W. J. MCCAULEY; *J. Eng. Ed.* **23**, 624–627, Apr., 1933. Describes a test which purports to measure visualizing ability in a way very closely related to the manner in which engineers both make and read drawings. Copies of the test may be had from the author, 459 Cottonwood Street, Globe, Arizona. D. R.

153. How do you think? GEORGE M. EATON; *Mech. Eng.* **55**, 279–280, May, 1933. Stimulated by the statement of R. E. Doherty (*Mech. Eng.* **55**, 90–94, Feb., 1933) that American engineering training is to be criticized because of the absence of a definite plan to inculcate in the minds of the students the habit of independent thought, the author, who is director of research for an industrial concern, describes a novel method of written analysis which he has worked out for use in the development of new machines, but which has proved to be applicable, in general principle, to any situation where it is necessary to gather and analyze data and reach a decision leading to action. D. R.

154. A Wisconsin philosophy of science teaching. I. C. DAVIS; *Phi Delta Kappan* **15**, 141–143, Feb., 1933. This is a committee report which represents the outgrowth of discussions in 55 groups in which 300 teachers participated. Education is "growth through problem solving" so that the individual may learn to act "in such a way that he will make the greatest possible contribution to society and at the same time receive the greatest personal satisfaction." In the light of this definition, the three general objectives of science teaching are: to develop an attitude which recognizes and attacks problems; to impart a scientific method which will be more efficient than a trial and error method; and to impart a fund of information which will make it unnecessary to repeat the experimentation which has produced our present civilization. Fourteen specific objectives are stated. Some of these are: power to distinguish between fact and theory; the concept of cause and effect relationship; habits of basing judgment on facts; ability to formulate workable hypotheses; willingness to change opinion on the basis of new evidence; and appreciation of possible future developments of science. D. R.

155. Report of the committee on college entrance requirements. BURTON L. CUSHING; *Sch. Sci. and Math.* **33**, 655–656, June, 1933. This committee of the Eastern Association of Physics Teachers suggests that the following changes be made in the syllabus for the high-school course in physics: "(1) That the syllabus be divided into two parts: (a) minimum essentials which should be included in all courses and (b) optional topics from which a choice could be made depending on the needs and equipment of different schools and localities. (2) That some of the newer physics such as cathode rays, ionization, the photoelectric effect, and the principles of radio, and modern refrigeration be included in the optional topics. (3) That a considerable amount of the mathematics be included under the optional topics. (4) That the examination also be in two parts, (a) required questions on the minimum essentials and (b) a choice among questions to be based on either more difficult phases of the minimum essentials or the optional topics, there being a sufficiently wide range of choice so that a pupil who has had a good course in physics should be sure to find enough questions he can answer to make up the total required number in the examination." D. R.

156. Sound motion pictures as an aid in science teaching. C. C. CLARK; *Sci. Ed.* **17**, 17–23, Feb., 1933. It is concluded from actual tests with identical subject matter that silent films give better results than sound films. D. R.

MISCELLANEOUS

161. The balancing of economic issues. COMMITTEE ON THE RELATION OF CONSUMPTION, PRODUCTION AND DISTRIBUTION, AMERICAN ENGINEERING COUNCIL; *Mech. Eng.* **55**, 211–224, Apr., 1933; 295–304, May, 1933. An analysis of 40 alleged causes of business instability, and of 23 out of more than 50 plans submitted for remedying business instability. D. R.